BASELINE HUMAN HEALTH RISK ASSESSMENT
DAVENPORT AND FLAGSTAFF SMELTER
SALT LAKE VALLEY, UTAH

Risks to Residents
From Arsenic and Lead in Soil

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Prepared for

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LIST OF ABBREVIATIONS AND ACRONYMS

BOR	Bureau of Reclamation
CDC	Centers for Disease Control
CT	Central Tendency
DI	Daily Intake
EDF	Empirical Continuous Distribution Function
EPC	Exposure Point Concentration
GM	Geometric Mean
GSD	Geometric Standard Deviation
HIF	Human Intake Factor
HQ	Hazard Quotient
ICP	Inductively Coupled Plasma
IEUBK	Integrated Exposure, Uptake, and Biokinetic Model
IR_{SD}	Soil and Dust Ingestion Rate
ISE	Integrated Stochastic Exposure Model
P10	Probability of a Blood Lead Value over 10µg/dL
PbB	Blood Lead
PDFs	Probability Density Functions
PRA	Probabilistic Risk Assessment
RBA	Relative Bioavailability
RfDs	Reference Doses
RME	Reasonable Maximum Exposure
SFs	Slope Factors
EPA	Environmental Protection Agency
UCL	Upper Confidence Limit
UDEQ	Utah Department of Environmental Quality
XRF	X-ray Fluorescence

EXECUTIVE SUMMARY

Site Description and History

The Davenport and Flagstaff smelter sites are located in the Southeast corner of the Salt Lake Valley. These smelters operated during the early to mid 1870's processing lead and copper ores. The area surrounding the former smelters currently consists of primarily residential, school and commercial areas. Little physical evidence of the smelters remains.

Basis For Potential Health Concern

In 1991, the discovery of ladle casts in Little Cottonwood Creek, near the Flagstaff smelter, prompted a study of historic smelter sites of the Salt Lake Valley. A Phase I site assessment found elevated concentrations of arsenic and lead in surface and subsurface soils near the Flagstaff Smelter site. Both the Phase II and Phase III assessments also revealed high levels and widespread existence of arsenic and lead contaminated soils surrounding the former smelters.

Site Investigation

Soil samples

A total of 220 surface soil samples (0-2") were collected from 40 properties within the residential area. Most properties were divided into four or more subzones (depending on the size of the property), and a composite surface soil sample was collected from within each subzone of the property. Each composite sample consisted of 10 separate sample locations (aliquots) within a subzone. The following table provides summary statistics for the concentrations of arsenic and lead in surface soils collected at this site.

Analyte	Detection Frequency	Non-Detects (mg/kg)		Detects (mg/kg)	
		Min	Max	Min	Max
Arsenic	219/220 (99.5%)	5	5	5	650
Lead	220/220 (100%)	--	--	12	27,000

Analysis of subsurface soil samples indicated that contamination is fairly uniform to a depth of at least 18 inches.

Dust Samples

Indoor dust samples (N=35) were obtained from a total of 11 residences within the study area. The resulting dust samples were analyzed via ICP for lead only. Full data are provided in Appendix 3. Summary statistics for measured lead dust concentrations are provided in the following table.

Lead		
Detection Frequency	**Mean (mg/kg)**	**Range (mg/kg)**
34 / 34*	110	32 – 225*

* One sample (6,796 ppm) was determined to be an outlier and was not included in this analysis

Linear regression analysis revealed no significant relationship between the concentration of lead in indoor dust and the concentration in outdoor soil. In order to be conservative, it was assumed that this finding was the consequence of data limitations (rather than an authentic lack of correlation), and studies on soil-dust relationships at other similar sites in Utah were used to estimate relationships for both lead and arsenic at this site.

Risks From Arsenic

Methods

Risks to residents from exposure to arsenic in soil were evaluated using standard USEPA methods. Direct contact (ingestion of soil and dust) was evaluated quantitatively. Other pathways were judged to be minor (dermal contact, inhalation of soil particles in air) or were evaluated qualitatively (ingestion of home-grown produce).

Exposure and Toxicity Parameters

All exposure and toxicity factors were based on standard USEPA defaults for residential exposure. The relative bioavailability of arsenic was estimated based on arsenic absorption studies in animals for samples from other sites, using information on the geochemical characteristics of arsenic bearing particles in site soils to identify which results are most similar. The value selected was 51%, which is slightly lower than the default value of 80%.

Exposure Areas

The health effect of chief concern for exposure to arsenic is increased risk of cancer. Because cancer is a chronic disease associated with long-term exposure, the appropriate exposure unit is the area over which a resident is exposed over the course of many years. Based on this concept, the residential area of this was divided into three zones (A-C) with zone C being further subdivided into four zones (C1-C4) as shown in Figure ES-1. The precise locations of the boundaries for each zone was largely judgmental, and were based mainly on the pattern of estimated arsenic concentration values and convenient natural boundaries such as current city streets.

Noncancer Risks

Noncancer risks are described in terms of the ratio of the dose at the site divided by a dose that is believed to be safe. This ratio is referred to as the Hazard Quotient (HQ). If the HQ is equal to or less than 1, it is believed that there is no appreciable risk that noncancer health effects will occur. If an HQ exceeds 1, there is some possibility that noncancer effects may occur, although an HQ above 1 does not indicate an effect will definitely occur. However, the larger the HQ value, the more likely it is that an adverse health effect may occur.

Estimated HQ values for residents exposed to arsenic in soil and dust under both average and reasonable maximum exposure (RME) conditions are shown below:

Zone	Average HQ	RME HQ
A	0.06	0.2
B	0.1	0.3
C (all)	0.08	0.2
C1	0.2	0.5
C2	0.05	0.1
C3	0.04	0.1
C4	0.06	0.2
All	0.08	0.2

All values shown are rounded to one significant figure

As seen, risks appear to be below a level of concern (i.e., HQ < 1) at all zones.

Cancer Risks

Risk of cancer from exposure to arsenic is described in terms of the probability that an exposed individual will develop cancer because of that exposure by age 70. The level of cancer risk that is of concern is a matter of individual, community and regulatory judgement. However, the U.S. EPA typically considers risks below 1 in a million to be so small as to be negligible, and risks above 100 per million to be sufficiently large that some sort of action or intervention is usually needed.

Estimated risks for residents exposed to arsenic in soil and dust are shown below:

Zone	Excess Lifetime Cancer Risk (per million)	
	Average	RME
A	3	30
B	7	60
C (all)	4	40
C1	10	100
C2	3	30
C3	2	20
C4	4	30
All	5	40

All values shown are rounded to one significant figure

As seen, average risk estimates range from 2 to 10, and RME risk estimates range from 20 to 100. No risk estimates exceeded a level of 100.

Uncertainties in Arsenic Risk Estimates

It is important to recognize that the exposure and risk calculations for arsenic presented in this section are based on a number of assumptions, and that these assumptions introduce uncertainty into the dose and risk estimates. Assumptions are required because of data gaps in our understanding of the toxicity of chemicals, and in our ability to estimate the true level of human exposure to chemicals. The main sources of uncertainty in the evaluation of arsenic risks to residents at this site include the following:

- Uncertainty in actual arsenic concentrations in soil and dust

- Uncertainty in the actual level of human exposure to soil and dust (default values are based on limited data)

- Uncertainty in the absorption (bioavailability) of arsenic in soil (the value used is based on studies from a different site)

- Uncertainty in the most appropriate toxicity values (reference dose and slope factor) for arsenic (debate continues in the toxicological community regarding the best way to quantify risk from arsenic)

- Uncertainty regarding the risks from exposure through ingestion of home-grown garden vegetables (available data were not adequate to allow quantitative evaluation of this pathway)

In most cases, assumptions employed in the risk assessment process to deal with uncertainties are intentionally conservative; that is, they are more likely to lead to an overestimate than an underestimate of risk. It is important for risk managers and the public to take these uncertainties into account when interpreting the risk conclusions derived for this site.

Conclusion Regarding Arsenic

Calculations above suggest that arsenic in soil at this site is likely to be within EPA's acceptable risk range for both average and RME residents.

Risks From Lead

Methods

Risks from lead are usually evaluated by estimation of the blood lead levels in exposed individuals and comparison of those blood lead values to an appropriate health-based guideline. In the case of residential exposure, the population of chief concern is young children (age 0-84 months). The EPA and CDC have set as a goal that there should be no more than a 5% chance that a child should have a blood lead value over 10 ug/dL. For convenience, the probability of exceeding a blood lead value of 10 ug/dL is referred to as P10.

Blood lead levels in an exposed population of children may either be measured directly, or may be calculated using a mathematical model. Each of these approaches has strengths and weaknesses, however, because measured blood lead values were not collected at this site, only a modeling approach was used.

Blood Lead Values Predicted with the IEUBK Model

The U.S. EPA has developed an integrated exposure, uptake and biokinetic (IEUBK) model to assess the risks of lead exposure in residential children. This model requires as input point estimates of the average concentration of lead in various environmental media in residential properties at the site, and the average amount of these media contacted by a child living at the site. These data are used to estimate the average blood lead value in an exposed child. Then, a distribution of blood lead values is estimated by assuming a lognormal distribution and applying an estimated geometric standard deviation (GSD).

All of the exposure parameters used as inputs to the IEUBK model were either site-specific concentration values (soil, dust, water) or were the standard EPA-recommended default values, except as follows:

- The concentration of lead in the diet was adjusted downwards by 30%, based on recent dietary survey data

- The relative bioavailability of lead in soil was assumed to be equal to EPA's default value of 60%.

- The GSD was assumed to be 1.4, based on data from blood lead studies at other sites in the area. However, a GSD of 1.6 was also evaluated.

The resulting predictions of the IEUBK model, stratified by zone, are shown below:

Zone	N	Min PbB (ug/dL)	Max PbB (ug/dL)	Mean PbB (ug/dL)	GSD = 1.4		GSD = 1.6	
					Average P10 (%)	Percent of properties with P10 > 5%	Average P10 (%)	Percent of properties with P10 > 5%
A	5	3	4	3.1	0.0	0	0.7	0
B	5	3	17	7.6	27.3	60	28.6	60
C (all)	30	2	28	5.2	12.2	17	12.9	23
C1	6	3	28	12.6	43.5	67	44.8	67
C2	8	2	5	3.1	0.6	0	2.3	25
C3	3	2	3	2.3	0.0	0	0.1	0
C4	13	2	21	3.8	7.6	8	7.7	8
All	40	2	28	5.3	12.5	20	13.4	25

As seen, at a GSD of 1.4, several of the zones have a large fraction of properties where there is greater than a 5% chance of exceeding a blood lead level of 10 ug/dL. The highest risks are predicted to occur in zones B and C (specifically C1, with some contribution from C4). Zones A, C2 and C3 have less than a 5% chance of exceeding a blood lead level of 10 ug/dL.

With a GSD of 1.6, the highest risks are still predicted to occur in zones B and C (specifically C1). However, now only zones A and C3 have less than a 5% chance of exceeding a blood lead level of 10 ug/dL.

Conclusion Regarding Lead

Based on the results of the IEUBK model, it is considered probable that lead levels in soil in this community are sufficiently high in a number of locations that there is risk that children will have elevated blood lead levels. Because direct measurements of blood lead levels in the community were not obtained, this model could be either over- or under-predicting actual risks. This model has been observed to overpredict risks to children from lead at several Western mining/smelting sites including; California Gulch, Sandy Smelter, Murray Smelter, Bingham Creek and Herriman. Therefore, it is more likely that risks are being overestimated rather than underestimated.

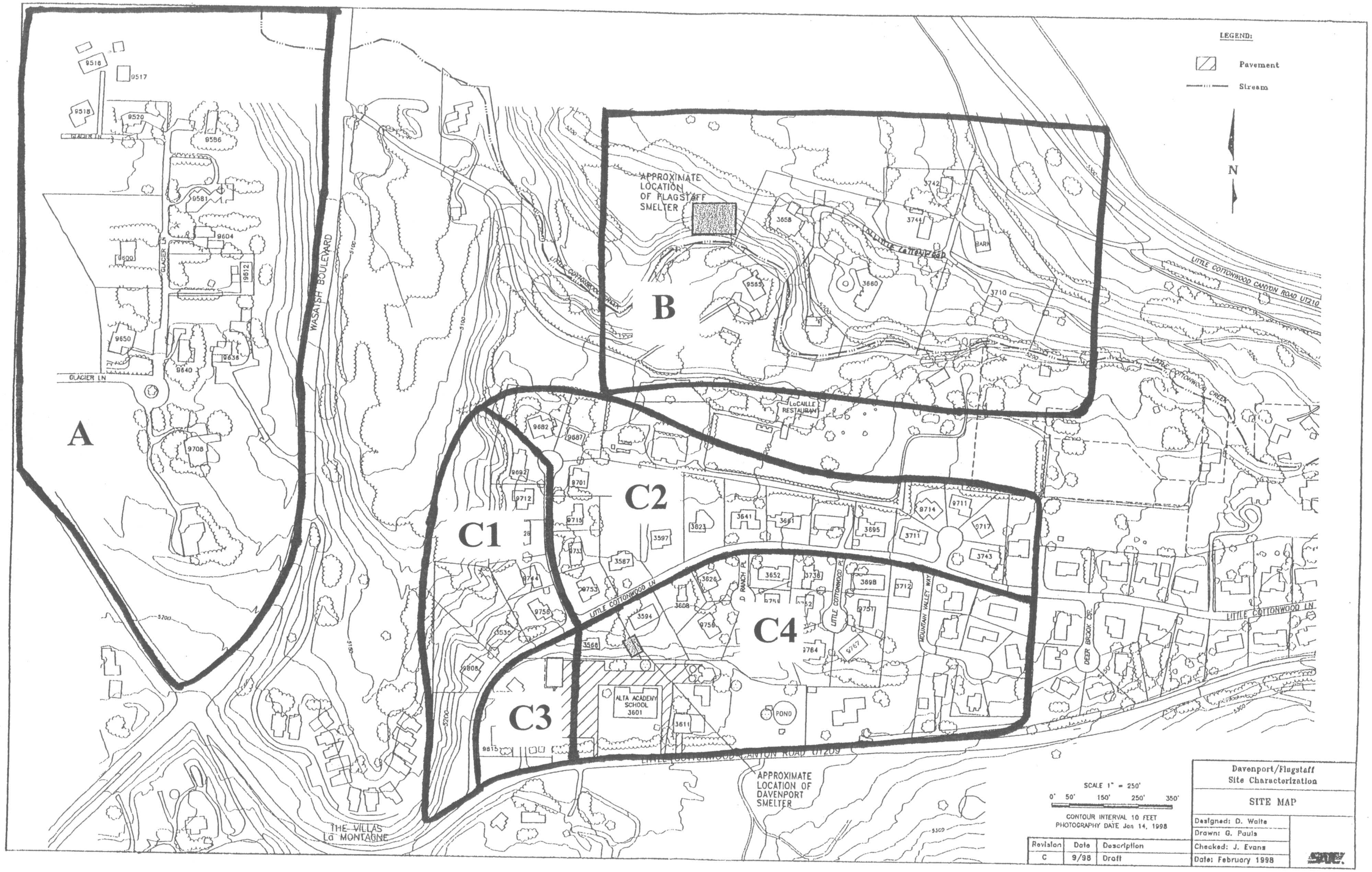


FIGURE ES-1 ZONE MAP

SECTION 1

INTRODUCTION

1.1 SITE DESCRIPTION AND HISTORY

The Davenport and Flagstaff smelter sites are located in the Southeast corner of the Salt Lake Valley (Figure 1-1). These smelters operated during the early to mid 1870's processing lead and copper ores. The area surrounding the former smelters currently consists of primarily residential, school and commercial areas. Little physical evidence of the smelters remain.

1.2 BASIS FOR POTENTIAL HEALTH CONCERN

In 1991, the discovery of ladle casts in Little Cottonwood Creek, near the Flagstaff smelter, prompted a study of historic smelter sites of the Salt Lake Valley. In April of 1992, a Phase I site assessment was conducted by the EPA Region 8, Emergency Response Branch, Technical Assistance Team (TAT). Elevated concentrations of arsenic and lead were found in surface and subsurface soils near the Flagstaff Smelter site. Based on these results, TAT conducted a Phase II site assessment in June of 1992. During this investigation, a second smelter site, known as the Davenport Smelter, was discovered south of the Flagstaff Smelter. The Davenport Smelter was investigated further in a Phase III site assessment. Both the Phase II and Phase III assessments revealed high levels and widespread existence of arsenic and lead contaminated soils surrounding the former smelters.

1.3 PURPOSE AND SCOPE OF THIS RISK ASSESSMENT

The purpose of this document is to characterize the nature and magnitude of risks which mining-related wastes pose to humans who may be exposed in the vicinity of the site.

This risk assessment focuses on current residents surrounding the two smelter sites. Based on experience at numerous other mining and smelting sites in the western United States, the chemicals of chief health concern to humans are arsenic and lead, so this evaluation focuses on the risks from these two contaminants. The environmental medium of chief concern is contaminated residential area soils, as well as other media (e.g., indoor dust, home-grown vegetables) that may become contaminated from the soil.

Information from this report will be used by risk managers to help make decisions as to whether the level of health risk posed by the mining/smelting related wastes is above acceptable limits, and if so, to help decide what actions are needed to protect public health.

SECTION 2

DATA SUMMARY

2.1 SOIL

2.1.1 Surface Soils

A total of 220 surface soil samples (0-2") were collected from 40 properties within the residential area. Most properties were divided into four or more subzones (depending on the size of the property), and a composite surface soil sample was collected from within each subzone of the property. Each composite sample consisted of 10 separate sample locations (aliquots) within a subzone. The surface samples collected within each subzone were dried, composited, homogenized, sieved to 250 um and analyzed via ICP analysis for lead. The following table provides summary statistics for the concentrations of arsenic and lead in surface soils collected at this site. Raw data are provided in Appendix 1.

Analyte	Detection Frequency	Non-Detects (mg/kg)		Detects (mg/kg)	
		Min	Max	Min	Max
Arsenic	219/220 (99.5%)	5	5	5	650
Lead	220/220 (100%)	--	--	12	27,000

2.1.2 Subsurface Soils

Soil borings were also collected at depth intervals of 0-6", 6-12" and 12-18" at 220 locations within the study area. Raw data are provided in Appendix 2. The following table presents summary statistics on the depth profiles of lead and arsenic in these samples.

Analyte	N	Depth	Avg (mg/kg)	Min (mg/kg)	Max (mg/kg)
Arsenic	220	0-2"	34.4	2.5	650
		0-6"	47.2	2.5	2,000
		6-12"	34.9	2.5	360
		12-16"	36.1	2.5	750
Lead	220	0-2"	773	12	27,000
		0-6"	692	13	19,000
		6-12"	603	14	9,500
		12-16"	569	17	12,000

Non-Detects Evaluated at ½ Detection Limit

As seen, there is no apparent gradient of concentrations of arsenic or lead in soil as a function of depth. On this basis, all calculations of exposure and risk were based on surface soil measurements (N=220). If subsurface soil were ever excavated and brought to the surface, risks would be similar to that for current surface soil.

2.2 INDOOR DUST

Indoor dust samples (N=35) were obtained from a total of 11 residences within the study area. Samples were collected from approximately three locations (each 25 cm^2) within each residence using a high flow vacuum sampler (HVS-3 Cyclone Sampler) (UDEQ 1998). These vacuum samples were collected from heavily traveled floor areas within each residence. The resulting dust samples were analyzed via ICP for lead only. Full data are provided in Appendix 3. Summary statistics for measured lead dust concentrations are provided in the following table.

Lead		
Detection Frequency	**Mean (mg/kg)**	**Range (mg/kg)**
34 / 34*	110	32 – 225*

* One sample (6,796 ppm) was determined to be an outlier and was not included in this analysis

The relationship between metal levels in indoor dust and in outdoor (yard) soil were investigated by fitting the data to an equation of the form:

$$C_d = k_0 + k_s * C_s$$

where:

C_d	=	Concentration in indoor dust (mg/kg)
k_0	=	contribution to indoor dust from non-yard soil sources (mg/kg)
k_s	=	mass fraction of yard soil in indoor dust (unitless)
C_s	=	Concentration in yard soil (mg/kg)

Figure 2-1 shows the relationship between average measured levels of lead in indoor dust at a house and the average concentration of lead in the soil of that house, along with the best-fit linear regression equation.

As seen, there is no apparent correlation between outdoor soil (adjusted values) and indoor dust for lead. It should be noted that the sample size (11 properties) may be too limited to observe an existing relationship. The lack of an apparent correlation suggests that soil is not an important source of lead in indoor dust. However, it is expected that outdoor soil should be a source of contamination in indoor dust, and studies at other sites usually do detect a significant correlation between contaminant levels in soil and dust. In order to determine an appropriate estimate of the relationship between lead in soil and indoor dust, observed relationships from similar sites were reviewed. Additionally, because no site-specific measurements were made for arsenic in indoor dust, observed arsenic relationships were also used.

Results from four smelting/mining sites in Utah are summarized in the table below.

Site	Observed Soil-Dust Relationship	
	Lead	Arsenic
Murray	$C_d = 174 + 0.19 \cdot C_s$	$C_d = 16 + 0.17 \cdot C_s$
Midvale	$C_d = 290 + 0.18 \cdot C_s$	$C_d = 20 + 0.23 \cdot C_s$
Sandy	$C_d = 77 + 0.15 \cdot C_s$	Not Evaluated
Bingham	$C_d = 90 + 0.43 \cdot C_s$	Not Evaluated

Based on the fact that significant relationships between soil and dust have been observed at similar sites, soil-dust relationships at this site were assumed to be similar to those from other sites. In order to be conservative, the soil dust relationships for lead and arsenic were each based on the equation which had the highest slope value, as follows.

<u>Arsenic:</u> Dust [As] = 20 + 0.23*Soil [As]

<u>Lead:</u> Dust [Pb] = 90 + 0.43*Soil [Pb]

2.3 TAP WATER

Residents of this area have their water supplied via a municipal water system, so contamination of drinking water is not suspected to be of concern. In similar communities supplied by municipal water systems, the concentration of lead in water is typically below the detection limit of 2 ug/L. It is assumed that conditions at this site are similar.

SECTION 3

RISKS FROM ARSENIC

3.1 EXPOSURE ASSESSMENT

3.1.1 Conceptual Site Model

Residents who live at properties where soil has been contaminated as a result of the historic mining and smelting activities could be exposed to arsenic by several different pathways, including the following:

- Incidental ingestion of contaminated soil or dust
- Dermal contact with contaminated soil or dust
- Inhalation of contaminated soil particles resuspended into air
- Ingestion of vegetables or fruits grown in contaminated soil

These pathways are illustrated in Figure 3-1. However, not all of these exposure pathways are believed to be of equal concern. Section 3.1.2 (below) presents a more detailed description of each of these exposure scenarios, and presents the basis for concluding that some pathways are minor.

3.1.2 Pathway Screening

Soil/Dust Ingestion

Although few humans intentionally ingest soil, a number of studies show that most people do ingest small amounts of soil and/or dust derived from the soil. Young children are thought to be especially likely to ingest soil and dust, mainly through hand-to-mouth activities, including mouthing of objects (toys, pacifier, etc.) that have soil or dust on them. Adults are also believed to ingest soil and dust through hand-to-mouth contact, both at home and in the workplace. Thus, this pathway is believed to be one of the most important mechanisms by which humans can be exposed to environmental contaminants, and this pathway was evaluated quantitatively.

Inhalation Exposure to Soil/Dust in Air

Arsenic is not volatile and does not exist in air except as part of soil or dust particles that becomes suspended in air as a result of wind or mechanical erosion. Although airborne levels of soil (and hence arsenic) can be high under conditions of extreme soil erosion, this pathway is normally a minor source of exposure. For example, using screening level estimates of human exposure recommended by USEPA (1996), the intake of soil from the inhalation pathway is less than 0.02% of the ingested dose (see Appendix 4). Based on this, it is concluded that exposure of area residents to arsenic by inhalation of airborne particles is likely to be minimal, and inhalation exposure was not considered further in this assessment.

Dermal Contact with Soil and Dust

Humans can be exposed to contaminated soil by getting it on their skin while working or playing outdoors, and may also have dermal contact with dust while indoors. However, current data on dermal absorption rates from soil or dust are not adequate to allow reliable estimation of the amount of most metallic contaminants absorbed across the skin (USEPA 1992b). Even though data are sparse, it is generally considered that metals in soil do not rapidly cross the skin, and screening level estimates suggest that this pathway is not likely to be a significant contributor, at least in comparison to the oral ingestion pathway (see Appendix 4). On this basis, this pathway was not evaluated quantitatively in this assessment.

Ingestion of Home-Grown Vegetables

Area residents could be indirectly exposed to soil contaminants via consumption of vegetables grown in contaminated soil. Evaluation of this pathway can be conducted by use of site-specific data (i.e., measured concentrations of arsenic in locally-grown produce), or through use of mathematical models that predict uptake of arsenic from soil into vegetables. No site-specific data are currently available for this pathway, and mathematical uptake models are generally quite uncertain and often tend to overestimate actual uptake levels. Therefore, this pathway is not addressed quantitatively in this risk assessment. A qualitative discussion of the potential risks from the garden vegetable pathway is presented in Section 3.6.5.

3.1.3 Summary of Pathways of Principal Concern

Based on the considerations above, only ingestion of soil and dust have been evaluated quantitatively in this risk analysis. Risk from garden vegetable intake is evaluated qualitatively. Other direct and indirect exposure pathways to soil are judged to be sufficiently minor that further quantitative evaluation is not warranted.

3.2 QUANTIFICATION OF EXPOSURE

3.2.1 Basic Equation

The magnitude of human exposure to chemicals in an environmental medium is described in terms of the average daily intake (DI), which is the amount of chemical which comes into contact with the body by ingestion, inhalation, or dermal contact. The general equation for calculating the daily intake from contact with an environmental medium is (USEPA 1989a):

$$DI = C \cdot IR \cdot EF \cdot ED \cdot RBA/(BW \cdot AT)$$

where:

DI = daily intake of chemical (mg/kg-d)
C = concentration of chemical in an environmental medium (e.g., mg/kg)
IR = intake rate of the environmental medium (e.g., kg/day)
RBA = relative bioavailability of chemical in site medium
EF = exposure frequency (days/yr)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (days)

For mathematical and computational convenience, this equation is often written as:

$$DI = C \cdot HIF \cdot RBA$$

where:

HIF = "Human Intake Factor". For soil and dust ingestion, the units of HIF are kg/kg-day. The value of HIF is given by:

$$HIF = IR \cdot EF \cdot ED/(BW \cdot AT)$$

There is often wide variability in the amount of contact between different individuals within a population. Thus, human contact with an environmental media is best thought of as a distribution of possible values rather than a specific value. Usually, emphasis is placed on two different portions of this distribution:

<u>Average</u> or <u>Central Tendency (CT)</u> refers to individuals who have average or typical intake of environmental media.

<u>Upper Bound</u> or <u>Reasonable Maximum Exposure (RME)</u> refers to people who are at the high end of the exposure distribution (approximately the 95th percentile). This evaluation is intended to assess exposures that are conservative (i.e., higher than average), but are still within a realistic range of exposure.

3.2.2 Exposure Parameters

The exposure parameters used in this risk assessment to calculate risk to residents from arsenic in soil are presented in Table 3-1, along with the resulting HIF values. All values are from standard EPA default values (USEPA 1989a, USEPA 1991a, USEPA 1993).

3.2.3 Concentration of Arsenic (C)

Soil

The concentration term in the basic equation above (see Section 3.2.1) is the arithmetic mean concentration of a contaminant, averaged over the location (Exposure Point) where exposure is presumed to occur during a specified time interval (USEPA 1989a). The location and size of the Exposure Points depends in part on human activity patterns and in part on the length of time that is required for a chemical to cause adverse effects. In this case, arsenic is of concern only for chronic (long-term) exposures, so the appropriate exposure unit is the area over which a resident is exposed over the course of many years. Based on this concept, the residential area was divided into three zones (A, B & C), each comprising several residences. These zones, shown in Figure 3-2, were used as the residential Exposure Point areas for this risk assessment. Due to variations in arsenic concentrations, zone C was subdivided further into four zones (C1, C2, C3 & C4). The precise locations of the boundaries for each zone is largely judgmental, and were based mainly on the pattern of arsenic concentration values, and convenient natural boundaries such as current city streets (Figure 3-3).

Because the true mean concentration of a chemical within an Exposure Point cannot be calculated with certainty from a limited set of measurements, the USEPA recommends that the upper 95th confidence limit (UCL) of the arithmetic mean concentration be used as the Exposure Point Concentration (EPC) in calculating exposure and risk (USEPA 1992a). If the calculated UCL is higher than the highest measured value, then the maximum value is used as the EPC instead of the UCL (USEPA 1992a).

In accord with this policy, EPCs were calculated using all surface soil results located within each zone. The following table presents summary statistics, including the Exposure Point Concentration, for each zone:

Zone	**N**	**Arsenic (mg/kg)**				
		Min	Max	Avg	UCL 95	EPC
A	32	11	64	23.3	26.8	27
B	42	9	370	54.4	74.1	74
C (all)	146	5	650	31.1	41.2	41
C1	29	10	650	77.3	124.2	124
C2	38	5	39	15.1	17.5	18
C3	12	7	17	10.7	12.1	12
C4	67	5	190	23.9	31.1	31
All	220	5	650	34	42	42

Dust

As described in Section 2.2, concentrations of arsenic in indoor dust may be estimated from arsenic levels in outdoor soil using the soil-dust relationship that was observed at a similar site (Midvale, Utah):

$$\text{Dust} = 20 + 0.23 \cdot \text{Soil}$$

3.2.4 Relative Bioavailability

Accurate assessment of the human health risks resulting from oral exposure to metals requires knowledge of the amount of metal absorbed from the gastrointestinal tract into the body. This information is especially important for environmental media such as soil or mine wastes, because metals in these media may exist, at least in part, in a variety of poorly water soluble minerals, and may also exist inside particles of inert matrix such as rock or slag. These chemical and physical properties may tend to influence (usually decrease) the absorption (bioavailability) of the metals when ingested.

Methods for Estimating Relative Bioavailability

The preferred method for obtaining site-specific estimates of relative bioavailability (RBA) of a metal in soil is to measure the gastrointestinal absorption in animals dosed with site soils compared to that for the metal dissolved in water. However, such tests are costly and take considerable time to perform, and no such animal data are available for any soil samples from this site. However, it is sometimes possible to estimate an appropriate RBA if absorption in animals has been measured in a soil sample that is similar to site soils. The definition of “similar” is judgmental, but is based on a general similarity in the nature and amount of different forms (“phases”) of arsenic in the samples. Therefore, data on the physical and chemical forms of arsenic in 10 different soils from the Davenport and Flagstaff smelter site were obtained. Arsenic concentrations in these samples was found to range from 7 to 350 mg/kg.

Characterization of Site Soils

Each sample of site soil was well mixed and analyzed by electron microprobe in order to identify a) how frequently particles of various arsenic minerals were observed, b) how frequently different types of arsenic particles occur entirely inside particles of rock or slag ("included") and how often they occur partially or entirely outside rock or slag particles ("liberated"), c) the size distribution of particles of each mineral class, and d) approximately how much of the total amount of arsenic in the sample occurs in each mineral type. This is referred to as "relative arsenic mass". Detailed results from this analysis are provided in Appendix 5.

As seen in Figure 3-4, the most common arsenic-bearing particle type (i.e., those which are observed most often) was iron oxide. The amount of arsenic mass in each phase is shown in Figure 3-5. As seen, a substantial portion of the mass occurs in the iron oxide phase, but the largest fraction of the mass exists in lead arsenic oxide.

Figure 3-6 shows the size distribution of the arsenic-bearing particles in the soil samples. As seen, the majority of particles were below 50 um in size. Small particles are often assumed to be more likely to adhere to the hands and be ingested and/or be transported into the house. Further, small particles have larger surface area-to-volume ratios than larger particles, and so may tend to dissolve more rapidly in the acidic contents of the stomach than larger particles. Thus, small particles (e.g. less than 50-100 um) are thought to be of greater potential concern to humans than larger particles (e.g., 100-250 um or larger).

Another property of arsenic particles that may be important in determining bioavailability is the degree to which the particles are partially or entirely free from surrounding matrix ("liberated"). Based on the measured frequency of each type of particle existing in a liberated state, it can be calculated that of the total relative arsenic present in each of the samples, approximately 100% exists in liberated particles. Nine out of 10 samples consisted of 100% liberated particles, whereas the remaining sample consisted of 98.7% liberated particles. These high percentages of partially or entirely liberated grains may tend to increase the bioavailability of arsenic in the samples.

Comparison with Other Samples

The physical-chemical characteristics of site samples were compared with the characteristics of a number of samples from other sites for which arsenic absorption data are available from tests in animals. Speciation data for these comparison samples are shown in Table 3-2. Based mainly on the pattern of principal phases, soils from the Davenport and Flagstaff Smelter site were judged to be most similar to a slag sample from the Murray Smelter site:

Arsenic Phase	**Relative Arsenic Mass (% Total)**	
	Davenport/Flagstaff Smelter*	**Murray Smelter**
PbAsO	68	49
FeO	12	--
AsFeO	9.9	27
Fe Sulfate	9	10

* Relative Arsenic Mass data from Sample #3656-559, which had highest levels of arsenic in samples tested

Selection of RBA Value to be Used

The Murray slag sample, when tested in animals (young swine) was found to have a relative bioavailability (RBA) factor of 0.51 for arsenic (WESTON, 1997). Based on the similarities between the site soils and the Murray slag sample, this factor was assumed to apply to soils from the Davenport and Flagstaff Smelter site and was utilized in this risk assessment. This value is somewhat lower than the default value of 0.80 that is used to evaluate arsenic in soil when no other site-specific data are available.

3.3 TOXICITY ASSESSMENT

3.3.1 Overview

The toxic effects of a chemical generally depend not only upon the inherent toxicity of the compounds and the level of exposure (dose), but also on the route of exposure (oral, inhalation, dermal) and the duration of exposure (subchronic, chronic or lifetime). Thus, a full description of the toxic effects of a chemical includes a listing of what adverse health effects the chemical may cause, and how the occurrence of these effects depend upon dose, route, and duration of exposure.

When data permit, the USEPA derives numeric values that are useful in quantifying the risk of noncancer and cancer effects of a chemical. For noncancer health effects, the values are termed References Doses (RfDs). These are route- and duration-specific estimates of the average daily intake (mg chemical/kg-day) that may occur without appreciable risk of any adverse effect.

For cancer, the USEPA assigns a weight-of-evidence category which summarizes the overall strength of the data supporting the conclusion that each chemical causes cancer in humans. These categories and their meanings are summarized below.

Category	Meaning	Description
A	Known human carcinogen	Sufficient evidence of cancer in humans.
B1	Probable human carcinogen	Suggestive evidence of cancer incidence in humans.
B2	Probable human carcinogen	Sufficient evidence of cancer in animals, but lack of data or insufficient data from humans.
C	Possible human carcinogen	Suggestive evidence of carcinogenicity in animals.
D	Cannot be evaluated	No evidence or inadequate evidence of cancer in animals or humans.

For chemicals which are classified in Group A, B, or C, the USEPA derives (if the data permit) a numeric descriptor of carcinogenic potency referred to as a Slope Factor (SF). These are route-specific estimates of the slope of the cancer dose-response curve at low doses. It is assumed that at low doses the curve is linear and passes through the origin. The units of the SFs are $(mg/kg\text{-}day)^{-1}$.

The following sections summarize the characteristic cancer and noncancer effects for oral exposure to arsenic, and list available toxicity parameters.

3.3.2 Adverse Effects of Arsenic

Excess exposure to arsenic is known to cause a variety of adverse health effects in humans. These effects depend on exposure level (dose) and also on exposure duration. The following sections discuss the most characteristic of these effects.

Noncancer Effects

Oral exposure to high doses of arsenic produces marked acute irritation of the gastrointestinal tract, leading to nausea and vomiting. Symptoms of chronic ingestion of lower levels of arsenic often begin with a vague weakness and nausea. As exposure continues, symptoms become more characteristic and include diarrhea, vomiting, decreased blood cell formation, injury to blood vessels, damage to kidney and liver, and impaired nerve function that leads to "pins and needles" sensations in the hands and feet. The most diagnostic sign of chronic arsenic exposure is an unusual pattern of skin abnormalities, including dark and white spots and a pattern of small "corns," especially on the palms and soles (ATSDR 1991).

The long-term (chronic) average daily intake of arsenic that produces these effects varies from person to person. In a large epidemiological study, Tseng et al. (1968) reported skin and vascular lesions in humans exposed to 1.4E-02 mg/kg/day or more arsenic through drinking water in Taiwan. These effects were not observed in a control population ingesting 8.0E-04 mg/kg/day. Based on this, the USEPA calculated a chronic oral reference dose (RfD) of 3.0E-04 mg/kg/day (USEPA 1996). This is a dose which is believed to be without significant risk of causing adverse noncancer effects in even the most susceptible humans following chronic exposure.

Carcinogenic Effects

There have been a number of epidemiological studies in humans which indicate that chronic inhalation exposure to arsenic is associated with increased risk of lung cancer (USEPA 1984, ATSDR 1991). In addition, there is strong evidence from a number of human studies that oral exposure to arsenic increases the risk of skin cancer (USEPA 1984, ATSDR 1991). The most common type of cancer is squamous cell carcinoma, which appears to develop from some skin corns. In addition, basal cell carcinoma may also occur, typically arising from cells not associated with the corns. Although these cancers may be easily removed, they can be painful and disfiguring and can be fatal if left untreated. Although the evidence is limited, there are some reports which indicate that chronic oral arsenic exposure may also increase risk of internal cancers, including cancer of the liver, bladder and lung, and that inhalation exposure may also increase risk of gastrointestinal, renal or bladder cancers (ATSDR 1991). Based on these data, USEPA has assigned arsenic to cancer weight of evidence Category A.

The amount of arsenic ingestion that leads to skin cancer is controversial. Based on a study of skin cancer incidence in Taiwanese residents exposed mostly to As(+3) in drinking water (Tseng et al. 1968, USEPA 1984), the USEPA has calculated a unit risk of 5E-05 $(ug/L)^{-1}$ corresponding to an oral slope factor of 1.5E+00 $(mg/kg/day)^{-1}$ (IRIS 1999). This study has been criticized on several grounds, including uncertainty about exposure levels, possible effects of poor nutrition in the exposed population, potential exposure to other substances besides arsenic, and lack of blinding in the examiners. Consequently, some quantitative uncertainty exists in the cancer potency factor derived from the Tseng data. Nevertheless, these criticisms do not challenge the fundamental conclusion that arsenic ingestion is associated with increased risk of skin cancer, and the Tseng study is considered to be the best study currently available for quantitative estimation of skin cancer risk.

There are good data to show that arsenic is metabolized by methylation in the body, and some researchers have suggested that this could lead to a threshold dose below which cancer will not occur. Although there are data which are consistent with this view, the USEPA has reviewed the available information (USEPA 1988a) and has concluded that the data are insufficient at present to establish that there is a threshold for arsenic-induced cancer.

3.3.3 Summary of Oral Toxicity Values

The toxicity factors derived by the USEPA for oral exposure to arsenic are summarized below:

Oral RfD $(mg/kg\text{-}d)^{-1}$	3E-04
Oral Slope Factor $(mg/kg\text{-}d)^{-1}$	1.5E+00

3.4 RISK CHARACTERIZATION

3.4.1 Overview

Risk characterization is the process of combining information on doses (Section 3.2) with toxicity information (Section 3.3) in order to estimate the nature and likelihood of adverse effects occurring in members of the exposed population. As explained earlier, this process is usually performed in two steps, the first addressing noncancer risks from chemicals of concern, and the second addressing cancer risks. The basic methods used to quantify noncancer and cancer risks are summarized below.

3.4.2 Noncancer Risk

Basic Equations

The potential for noncancer effects from exposure to a chemical is evaluated by comparing the estimated daily intake of the chemical over a specific time period with the RfD for that chemical derived for a similar exposed period. This comparison results in a noncancer Hazard Quotient, as follows (USEPA 1989a):

$$HQ = DI/RfD$$

where:

HQ = Hazard Quotient

DI = Daily Intake (mg/kg-day)

RfD = Reference Dose (mg/kg-day)

If the HQ for a chemical is equal to or less than one (1E+00), it is believed that there is no appreciable risk that noncancer health effects will occur. If an HQ exceeds 1E+00, there is some possibility that noncancer effects may occur, although an HQ above 1E+00 does not indicate an effect will definitely occur. This is because of the margin of safety inherent in the derivation of all RfD values (see Section 3.6). However, the larger the HQ value, the more likely it is that an adverse effect may occur.

Results

Figure 3-7 and the following table summarize the estimated HQ values for residents exposed to estimated soil concentrations of arsenic by ingestion of soil and dust. As shown, none of the zones exceeds an HQ of 1E+00 under either average or RME exposure conditions.

Zone	Average HQ	RME HQ
A	6E-02	2E-01
B	1E-01	3E-01
C (all)	8E-02	2E-01
C1	2E-01	5E-01
C2	5E-02	1E-01
C3	4E-02	1E-01
C4	6E-02	2E-01
All	8E-02	2E-01

3.4.3 Cancer Risk

Basic Equations

The risk of cancer from exposure to a chemical is described in terms of the probability that an exposed individual will develop cancer because of that exposure by age 70. For each chemical of concern, this value is calculated from the daily intake of the chemical from the site, averaged over a lifetime (DI_L), and the SF for the chemical, as follows (USEPA 1989a):

$$\text{Cancer Risk} = 1 - \exp(-DI_L \cdot SF)$$

In most cases (except when the product of DI_L*SF is larger than about 0.01), this equation may be accurately approximated by the following:

$$\text{Cancer Risk} = DI_L \cdot SF$$

The level of cancer risk that is of concern is a matter of individual, community and regulatory judgement. However, the USEPA typically considers risks below 1E-06 to be so small as to be negligible, and risks above 1E-04 to be sufficiently large that some sort of action or intervention is usually needed (USEPA 1991b). Risks between 1E-04 and 1E-06 usually do not require action (USEPA 1991b), but this is evaluated on a case by case basis.

Results

Using these equations, the estimated lifetime average and RME daily intake values (calculated as described in Section 3.2) were combined with the oral slope factor for arsenic discussed in Section 3.3. The detailed calculations are presented in Appendix 6, and the results are summarized in Figure 3-7 and the following table.

Zone	**Excess Lifetime Cancer Risk**	
	Average	**RME**
A	3E-06	3E-05
B	7E-06	6E-05
C (all)	4E-06	4E-05
C1	1E-05	1E-04
C2	3E-06	3E-05
C3	2E-06	2E-05
C4	4E-06	3E-05
All	5E-06	4E-05

As seen, average risk estimates range from 2E-06 to 1E-05, and RME risk estimates range from 2E-05 to 1E-04. Risks above 1E-04 are not predicted for any zone at this site.

3.5 BIOMONITORING

A second approach for evaluating the level of human exposure to arsenic is to measure the level of arsenic that is excreted in the urine. This is because any arsenic which is absorbed into the body is largely excreted in the urine within 1-3 days.

Arsenic in the urine is composed of two basic types:

- Inorganic arsenic (and its metabolites), derived from environmental sources such as contaminated soil. This form of arsenic is toxicologically active and is of potential health concern. The concentration of inorganic arsenic in urine from non-exposed individuals is generally less than 50 ug/L (ACGIH, 1998).

- Organic arsenic, derived from dietary sources such as seafood. This form has very low toxicity and is of little or minor health concern. Very high levels of organic arsenic can be observed in urine following ingestion of seafood or other meals rich in dietary form of arsenic.

A biomonitoring study was not conducted at this site. Therefore, this approach is not utilized in this report.

3.6 UNCERTAINTIES

It is important to recognize that the exposure and risk calculations for arsenic presented in this section are based on a number of assumptions, and that these assumptions introduce uncertainty into the dose and risk estimates. Assumptions are required because of data gaps in our understanding of the toxicity of chemicals, and in our ability to estimate the true level of human exposure to chemicals. In most cases, assumptions employed in the risk assessment process to deal with uncertainties are intentionally conservative; that is, they are more likely to lead to an overestimate than an underestimate of risk. It is important for risk managers and the public to take these uncertainties into account when interpreting the risk conclusions derived for this site.

3.6.1 Uncertainties in Concentration Estimates

Evaluation of human health risk at any particular location requires accurate information on the average concentration level of arsenic at that location. However, concentration values may vary from sample to sample, so the U.S. EPA recommends that the 95% upper confidence limit of the mean be used in evaluation of both average and RME exposure and risk. This approach ensures that all of the risk estimates presented in this report are more likely to be high than low.

3.6.2 Uncertainties in Human Intake

As discussed in Section 3.2, there is usually wide variation between different individuals with respect to the level of contact they may have to chemicals in the environment. This introduces uncertainty into the most appropriate values to use for exposure parameters such as soil and dust intake rates, number of years at the residence, etc. Because of the uncertainty in the most appropriate values for these parameters, the USEPA generally recommends default values that are more likely to overestimate than underestimate exposure and risk.

3.6.3 Uncertainties in Toxicity Values

One of the most important sources of uncertainty in a risk assessment is in the RfD values used to evaluate noncancer risk and in the slope factors used to quantify cancer risk. In many cases, these values are derived from a limited toxicity database, and this can result in substantial uncertainty, both quantitatively and qualitatively. For example, there is continuing scientific debate on the accuracy of the oral slope factor and the oral Reference Dose for arsenic and whether or not they are accurate and appropriate for predicting hazards from relatively low dose exposures. In order to account for these and other uncertainties associated with the evaluation of toxicity data, both RfDs and SFs are derived by the USEPA in a way that is intentionally conservative; that is, risk estimates based on these RfDs and SFs are more likely to be high than low.

3.6.4 Uncertainties in Absorption from Soil

Another important source of uncertainty regarding the toxicity of arsenic is the degree to which it is absorbed into the body from ingested soil. Toxicity factors (RfD, oSF) for arsenic are based on observed dose response relationships when exposure occurs by ingestion of arsenic dissolved in water. If arsenic in soil is not absorbed as well as arsenic in water, use of unadjusted toxicity factors will tend to overestimate risk. At this site, a relative bioavailability factor for arsenic was estimated based on data from samples that appeared to be similar in metal-phase composition. However, use of this factor is uncertain because of possible differences between the samples.

As discussed previously, the default value of 0.80 is generally used to evaluate arsenic in soil when no other site-specific data are available. For this site, soil speciation data were compared to data from samples previously tested in juvenile swine. Because there is uncertainty surrounding the selection of the site specific value of 0.51, non-cancer and cancer risks were also evaluated using the default RBA factor of 0.80 as presented below and in Figure 3-8.

The following table summarizes the estimated HQ values for residents exposed to soil concentrations of arsenic by ingestion of soil and dust using an RBA factor of 0.80. As shown, none of the zones exceeds an HQ of 1E+00 under either average or RME exposure conditions.

Zone	Average HQ	RME HQ
A	9E-02	3E-01
B	2E-01	5E-01
C (all)	1E-01	3E-01
C1	3E-01	8E-01
C2	7E-02	2E-01
C3	6E-02	2E-01
C4	1E-01	3E-01
All	1E-01	3E-01

The following table summarizes the estimated risk values for residents exposed to soil concentrations of arsenic by ingestion of soil and dust using an RBA factor of 0.80. As shown by the shaded cells, only one zone (C-1) exceeds a risk level of 1E-04 under RME exposure conditions.

Zone	Excess Lifetime Cancer Risk	
	Average	RME
A	5E-06	5E-05
B	1E-05	1E-04
C (all)	7E-06	7E-05
C1	2E-05	2E-04
C2	4E-06	4E-05
C3	4E-06	3E-05
C4	6E-06	5E-05
All	7E-06	7E-05

3.6.5 Uncertainties from Pathways Not Evaluated

As discussed in Section 3.1.2, not all possible pathways of human exposure to arsenic were evaluated quantitatively in this risk assessment, and omission of these pathways presumably leads to some degree of underestimation of total risk. For some of these pathways (inhalation of arsenic in airborne dust, dermal absorption of arsenic from soil on the skin), the underestimation of risk is believed to be minimal. In the case of ingestion from home-grown garden vegetables, the magnitude of the underestimation is less certain. Studies at other sites (Sverdrup, 1995) suggest that exposure by this pathways is probably not as large as by oral exposure, but that the contribution is not completely negligible. However, the magnitude of this risk contributed by pathway is expected to vary widely from site to site, depending on the amount of uptake from soil into plants and the amount and type of produce actually grown and consumed by area residents.

3.7 CONCLUSION

Calculations above suggest that arsenic in soil at the Davenport and Flagstaff Smelter site is likely to be within EPA's acceptable risk range for both average and RME residents.

SECTION 4

RISKS FROM LEAD

4.1 ADVERSE EFFECTS OF LEAD EXPOSURE

Excess exposure to lead can result in a wide variety of adverse effects in humans. Chronic low-level exposure is usually of greater concern for young children than older children or adults. There are several reasons for this focus on young children, including the following: 1) young children typically have higher exposures to lead-contaminated media per unit body weight than adults, 2) young children typically have higher lead absorption rates than adults, and 3) young children are more susceptible to effects of lead than are adults. The following sections summarize the most characteristic and significant of the adverse effects on lead on children, and current guidelines for classifying exposures as acceptable or unacceptable.

4.1.1 Neurological Effects

The effect of lead that is usually considered to be of greatest concern in children is impairment of the nervous system. Many studies have shown that animals and humans are most sensitive to the effects of lead during the time of nervous system development, and because of this, the fetus, infants and young children (0-6 years of age) are particularly vulnerable. The effects of chronic low-level exposure on the nervous system are subtle, and normally cannot be detected in individuals, but only in studies of groups of children. Common measurement endpoints include various types of tests of intelligence, attention span, hand-eye coordination, etc. Most studies observe effects in such tests at blood lead levels of 20-30 µg/dL, and some report effects at levels as low as 10 µg/dL and even lower. Such effects on the nervous system are long-lasting and may be permanent.

4.1.2 Effects on Pregnancy and Fetal Development

Studies in animals reveal that high blood lead levels during pregnancy can cause fetotoxic and teratogenic effects. Some epidemiologic studies in humans have detected an association between elevated blood lead levels and endpoints such as decreased fetal size or weight, shortened gestation period, decreased birth weight, congenital abnormalities, spontaneous abortion and stillbirth (USEPA 1986). However, these effects are not detected consistently in different studies, and some researchers have detected no significant association between blood lead levels and signs of fetotoxicity. On balance, these data provide suggestive evidence that blood lead levels in the range of 10-15 µg/dL may cause small increases in the risk of undesirable prenatal as well as postnatal effects, but the evidence is not definitive.

4.1.3 Effects on Heme Synthesis

A characteristic effect of chronic high lead exposure is anemia stemming from lead-induced inhibition of heme synthesis and a decrease in red blood cell life span. ACGIH (1995) concluded that decreases in ALA-D activity (a key early enzyme involved in heme synthesis) can be detected at blood lead levels below 10 ug/dL. Heme synthesis is inhibited not only in red blood cells but in other tissues. Several key enzymes that contain heme, including those needed to form vitamin D, also show decreased activity following lead exposure (USEPA 1986). The CDC (1991) reviewed studies on the synthesis of an active metabolite of vitamin D and found that impairment was detectable at blood lead levels of 10 - 15 ug/dL.

4.1.4 Cancer Effects

Studies in animals indicate that chronic oral exposure to very high doses of lead salts may cause an increased frequency of tumors of the kidney (USEPA 1989b, ACGIH 1995). However, there is only limited evidence suggesting that lead may be carcinogenic in humans, and the noncarcinogenic effects on the nervous system are usually considered to be the most important and sensitive endpoints of lead toxicity (USEPA 1988b). ACGIH (1995) states that there is insufficient evidence to classify lead as a human carcinogen.

4.1.5 Current Guidelines for Protecting Children From Lead

It is currently difficult to identify what degree of lead exposure, if any, can be considered safe for infants and children. As discussed above, some studies report subtle signs of lead-induced effects in children and perhaps adults beginning at around 10 ug/dL or even lower, with population effects becoming clearer and more definite in the range of 30-40 ug/dL. Of special concern are the claims by some researchers that effects of lead on neurobehavioral performance, heme synthesis, and fetal development may not have a threshold value, and that the effects are long-lasting (USEPA 1986). On the other hand, some researchers and clinicians believe the effects that occur in children at low blood lead levels are so minor that they need not be cause for concern.

After a thorough review of all the data, the USEPA identified 10 ug/dL as the concentration level at which effects begin to occur that warrant avoidance, and has set as a goal that there should be no more than a 5% chance that a child will have a blood lead value above 10 ug/dL (USEPA 1991b). Likewise, the Centers for Disease Control (CDC) has established a guideline of 10 ug/dL in preschool children which is believed to prevent or minimize lead-associated cognitive deficits (CDC 1991).

4.2 METHODS FOR ASSESSING LEAD RISKS IN A COMMUNITY

The health risks which lead poses to a residential population can often be investigated in two different ways:

- Direct measurement of blood lead values in members of the population of concern.
- Measurement of lead in environmental media, and calculation of the range of risks those levels of lead could pose to individuals or populations.

As discussed below, each of these approaches has some advantages and some limitations, and the best assessment of lead risks incorporates the results of both types of approaches.

4.2.1 Blood Lead Monitoring

One way to investigate human health risks from lead in the environment is to measure the concentration of lead in the blood (PbB) in randomly-selected members of the population of concern. Such data allow comparison of site statistics (mean blood lead, percent of the population above 10 ug/dL, etc.) with corresponding national average statistics, in order to obtain a general sense of how much impact site contamination may have caused in the population. Further, the site statistics can be compared with health-based objectives and guidelines in order to determine if population-based health goals are being exceeded. In addition, blood lead studies which include reliable data on lead levels in various environmental media (soil, dust, paint, water, food) and which obtain reliable demographics data (age, sex, race, mouthing frequency, dietary status, etc.) can provide valuable insights into the media and exposure pathways that are the primary sources of concern in a population. For example, an analysis of the relationship between blood lead and lead levels in soil can help reveal how important soil is as a source of blood lead.

However, there are some important limitations to the use of blood lead measurements as the only index of lead risk. First, care must be taken to ensure that a sufficient number of people are studied, and that these people are a representative sub-set of the population of concern. Second, blood lead values in an individual may vary as a function of time, so a single measurement may not be representative of the long-term average value in that individual. Third, because of the variability between people in contact rates for various media, it is expected that blood lead values will differ (either lower or higher) between individuals, even when they are exposed under the same environmental conditions. Thus, a blood lead level that is below a level of concern in one child living at a specific residence does not necessarily mean that some other child who might be exposed at the same location might not have a higher (and possibly unacceptable) blood lead level. Fourth, population-based studies are not well-suited for detecting the occurrence of occasional sub-locations where risk is elevated, even if average risks are not above a level of concern. Finally, blood lead measurements reflect exposures and risks under current site conditions and population characteristics, which may not always be representative of past or future site conditions. For these reasons, results from blood lead studies may not provide a complete description of the range of risks which different members of a population might experience.

4.2.2 Modeling Approach

Because of the limitations in the direct measurement approach, it is often useful to employ mathematical models as well as empirical methods for evaluation of lead risk. These models can then be used to assess the risks from lead under conditions which cannot be measured (e.g., risks to hypothetical future people in areas where there are no current exposures), to identify which exposure pathways are likely to be contributing the largest risk to a population, and to evaluate the likely efficacy of various remedial alternatives.

The standard model developed by the USEPA to assess the risks of lead exposure in residential children is referred to as the Integrated Exposure Uptake and Biokinetic (IEUBK) model. This model requires as input data on the levels of lead in various environmental media at a specific location, and on the amount of these media contacted by a child living at that location. All of these inputs to the IEUBK model are central tendency point estimates (i.e., arithmetic means or medians). These point estimates are used to calculate an estimate of the central tendency (the geometric mean) of the distribution of blood lead values that might occur in a population of children exposed to the specified conditions. Assuming the distribution is lognormal, and given (as input) an estimate of the variability between different children (this is specified by the geometric standard deviation or GSD), the model calculates the expected distribution of blood lead values, and estimates the probability that any random child might have a blood lead value over 10 ug/dL.

USEPA Region VIII has been working to develop a variant of the IEUBK model in which variability in exposure between people and between locations is accounted for by using Probability Density Functions (PDFs) to specify inputs (rather than point estimates). This probabilistic model is referred to as the Integrated Stochastic Exposure (ISE) model (SRC 1999).

This type of approach is in keeping with USEPA policy (USEPA 1997), which states:

> *"It is the policy of the U.S. Environmental Protection Agency that such probabilistic analysis techniques as Monte Carlo analysis, given adequate supporting data and credible assumptions, can be viable statistical tools for analyzing variability and uncertainty in risk assessments. As such, and provided that the conditions described below are met, risk assessments using Monte Carlo analysis or other probabilistic techniques will be evaluated and utilized in a manner that is consistent with other risk assessments submitted to the Agency for review or consideration."*

and

"Use of Monte Carlo or other such techniques shall not be cause, per se, for the rejection of the risk assessment by the Agency."

This model has been used to evaluate lead risks at another mining/smelting site in Utah (Griffin et al. 1999a), but because the model has not undergone a full peer review or validation, it is considered to be only an investigative tool. Nevertheless, the ISE model does offer an alternative means of assessing exposure and risk from lead at the site.

The ISE model has not been used to evaluate risks to children at this site, based on direct instruction from senior USEPA management (Appendix 7) at a similar site.

Limitations to Modeling

All predictive models, including the IEUBK model, are subject to a number of limitations. First, there is inherent difficulty in providing the models with reliable estimates of human exposure to lead-contaminated media. For example, exposure to soil and dust is difficult to quantify because human intake of these media is likely to be highly variable, and it is very difficult to derive accurate measurements of actual intake rates. Second, it is often difficult to obtain reliable estimates of key pharmacokinetic parameters in humans (e.g., absorption fraction, distribution and clearance rates), since direct observations in humans are limited. Finally, the absorption, distribution and clearance of lead in the human body is an extremely complicated process, and any mathematical model intended to simulate the actual processes is likely to be an over-simplification. Consequently, model calculations and predictions are generally rather uncertain.

4.2.3 Weight-of-Evidence Evaluation

As the discussions above make clear, there are advantages and limitations to both the direct blood measurement approach and the predictive (mathematical modeling) approach. Therefore, when data are available to perform both types of analysis, the most appropriate means for evaluating risks from lead is to weigh the results of both analyses, taking into account the uncertainties and limitations of each. Final conclusions regarding current and future risk should thus be based on a balanced assessment of information from all sources.

4.3 DIRECT BLOOD LEAD OBSERVATIONS

No direct blood lead observations were obtained for this site, therefore, this approach is not utilized in this report.

4.4 IEUBK MODEL ANALYSIS

The IEUBK model is recommended by the USEPA to evaluate risks of lead exposure in children on a property-by-property basis. This approach is detailed below.

4.4.1 Model Inputs

A detailed printout of the input values used to evaluate lead risks at each property is presented in Appendix 8. The following sections summarize the input parameters used for these calculations.

Lead Concentration in Outdoor Yard Soil

Data on lead levels in surface soil (0-2 inches) have been obtained for 40 different properties in Zones A-C of the Study Area. A map of the site showing the concentrations of lead in surface soils is provided in Figure 4-1. Typically, about 4 samples were collected per property (dependent on property size), with each sample being a composite of ten subsamples. For the purposes of this analysis, all of the samples from a property were averaged to yield a single representative mean concentration for that property.

Lead Concentration in Indoor Dust

As described in Section 2.2, concentrations of lead in dust at a property can be estimated from the measured level of lead in soil at the property using the following assumed soil-dust relationship:

$$\text{Dust [Pb]} = 90 + 0.43 * \text{AdjSoil[Pb]}$$

As noted previously, this relationship is extrapolated from a similar site in Utah, since site-specific data did not reveal a significant correlation between lead in dust and lead in soil, possibly due to the limited number of dust samples collected at the site.

Water and Air

For this analysis, lead concentrations in water at each property were assigned a value of 1 ug/L. Lead values for air were kept at IEUBK default values.

Diet

The default values of lead intake from the diet in the IEUBK model are based on dietary data from 1982 – 1988. Recent FDA data provide strong evidence that concentrations of lead in food have continued to decline since 1988. Based on interpretations of the data, and an extrapolation from the downward trend observed in the 1980's, it has been estimated that the average lead intake from food by children has declined by approximately 30% (Griffin et al., 1999b). Therefore the dietary values were obtained by multiplying the model default values by a factor of 0.70.

Age

Predicted blood lead values were calculated at each property for a child 50 months of age. This age was selected since the value at 50 months is very similar to the long-term average blood average blood lead predicted for months 6 to 84.

Absorption Fraction for Lead in Soil

The absorption fraction is a measure of the amount of metal absorbed from the gastrointestinal tract into the body. This information is especially important for environmental media such as soil or mine wastes, because metals in these media may exist, at least in part, in a variety of poorly water soluble minerals, and may also exist inside particles of inert matrix such as rock or slag. These chemical and physical properties may tend to influence (usually decrease) the absorption (bioavailability) of the metals when ingested.

As discussed above, the preferred method for obtaining absorption data on lead in soil or other mines wastes is through tests in animals. However, no such in vivo data for lead absorption are available for soils from this site. However, it is sometimes possible to estimate availability values in a soil by extrapolation from other similar soils that have been tested in animals. In order to judge which soil is the most appropriate basis for extrapolation, it is necessary to compare information on the chemical and physical characteristics of lead in the site soils with those in the soils that have been tested in animals.

The characteristics of lead-bearing particles in 10 soil samples from the site were characterized using the same electron microprobe techniques described earlier. These samples had lead concentrations ranging from 24 to 9,200 mg/kg. Detailed results from this analysis are provided in Appendix 6, and the results are summarized below.

Characteristics of Site Soils

As seen in Figure 4-2, the most common lead-bearing particle types (i.e., those which are observed most often) were Fe Oxide, Phosphate and Mn Oxide. However, as Figure 4-3 shows, the primary phases which contribute to the majority of the relative lead mass are variable depending on the individual sample. In the sample with the highest lead concentration (9,200 mg/kg), cerussite contained the majority of the lead mass, however, this phase was not observed in the other site samples. In the sample with the second highest lead concentration (5700 mg/kg), anglesite was found to contain the majority of the lead mass, however, this phase was observed in only one other site sample. In the remaining 8 soil samples (range 24 – 2,000 mg/kg), a more consistent trend was seen in the mineral phases by concentration (Figure 4-4), with Phosphate, Fe Oxide and Mn Oxide containing the majority of the lead mass.

Figure 4-5 shows the distribution of the size of lead-bearing particles in the samples. As seen, the majority of particles were below 50 um in size. As noted above, small particles are often assumed to be more likely to adhere to the hands and be ingested and/or be transported into the house. Further, small particles have larger surface area-to-volume ratios than larger particles, and so may tend to dissolve more rapidly in the acidic contents of the stomach than larger particles. Thus, small particles (e.g. less than 50-100 um) are thought to be of greater potential concern to humans than larger particles (e.g., 100-250 um or larger).

Another property of lead particles that may be important in determining bioaccessability and/or bioavailability is the degree to which they are partially or entirely free from surrounding matrix ("liberated"). Based on the measured frequency of each type of particle existing in a liberated state, it can be calculated that of the total relative arsenic present in each of the samples, approximately 100% exists in liberated particles. Nine out of 10 samples consisted of 100% liberated particles, whereas the remaining sample consisted of 98.7% liberated particles. These high percentages of partially or entirely liberated grains may tend to increase the bioavailability of lead in the samples.

Comparison with Other Samples

An attempt was made to compare the physical-chemical characteristics of site samples with the characteristics of a number of samples from other sites for which lead absorption data are available from tests in animals. However, due to the variability in the pattern of principal phases, particularly at high lead concentrations, it was judged that the absorption fraction for soils from the Davenport and Flagstaff Smelter site could not be reliably estimated by extrapolating from tested samples. Therefore, the EPA default value of 0.60 will be retained as the RBA at this site.

GSD

The GSD recommended as the default for the IEUBK model is 1.6 (USEPA 1994). However, several blood lead studies that have been performed in the Salt Lake City area have yielded GSD estimates of about 1.4 (Griffin et al., 1999b). Therefore, both values of 1.4 and 1.6 were evaluated in this assessment.

Other Model Inputs

Default parameters for the IEUBK model were retained for all other model inputs used in this analysis.

4.4.2 Results – IEUBK Model Output

Using the input parameters identified above, geometric mean blood lead values were calculated for each property using the IEUBK model. Detailed calculations are presented in Appendix 8, and the results are shown in Figure 4-6, stratified by zone. As seen, many of the properties have predicted geometric mean blood lead levels which are above a benchmark of 10 ug/dL. Assuming these values are from a lognormal distribution with a GSD of either 1.4 or 1.6, the probability that a random child would have a blood lead value above 10 ug/dL can be calculated for each property (this probability is referred to as "P10"). The results are summarized below:

Zone	N	Min PbB (ug/dL)	Max PbB (ug/dL)	Mean PbB (ug/dL)	GSD = 1.4		GSD = 1.6	
					Average P10 (%)	Percent of properties with P10 > 5%	Average P10 (%)	Percent of properties with P10 > 5%
A	5	3	4	3.1	0.0	0	0.7	0
B	5	3	17	7.6	27.3	60	28.6	60
C (all)	30	2	28	5.2	12.2	17	12.9	23
C1	6	3	28	12.6	43.5	67	44.8	67
C2	8	2	5	3.1	0.6	0	2.3	25
C3	3	2	3	2.3	0.0	0	0.1	0
C4	13	2	21	3.8	7.6	8	7.7	8
All	40	2	28	5.3	12.5	20	13.4	25

As seen, at a GSD of 1.4, several of the zones have a large fraction of properties where there is greater than a 5% chance of exceeding a blood lead level of 10 ug/dL. The highest risks are predicted to occur in zones B and C (specifically C1, with some contribution from C4). Zones A, C2 and C3 have less than a 5% chance of exceeding a blood lead level of 10 ug/dL.

With a GSD of 1.6, the highest risks are still predicted to occur in zones B and C (specifically C1). However, now only zones A and C3 have less than a 5% chance of exceeding a blood lead level of 10 ug/dL.

4.5 UNCERTAINTIES

It is important to recognize that the exposure and risk calculations presented in this document are based on a number of assumptions, and that these assumptions introduce uncertainty into the dose and risk estimates. Assumptions are required because of data gaps in our understanding of the toxicity of chemicals, and in our ability to estimate the true level of human exposure to chemicals. In most cases, assumptions employed in the risk assessment process to deal with uncertainties are intentionally conservative; that is, they are more likely to lead to an overestimate rather than an underestimate of risk. It is important for risk managers and the public to take these uncertainties into account when interpreting the risk conclusions derived for this site.

4.5.1 Uncertainties in Concentration Estimates

Evaluation of human health risk at any particular location requires accurate information on the average concentration level of a chemical present at that location. For this site, the exposure unit was based on an individual property. The average concentration of lead at each property was used as input into the IEUBK model. EPA policy requires that evaluation of a child's risk to lead be based on the assumption that the child only receives exposure from his/her own home and yard. This assumption may or may not be realistic depending on the site, and may introduce a great deal of uncertainty into the risk estimate.

4.5.2 Uncertainties in Absorption from Soil

Another important source of uncertainty regarding the toxicity factors for the chemicals of concern at this site is bioavailability. Toxicity factors are often based on observed dose response relationships when the chemical exists dissolved in water, or in some other readily soluble form. However, metals in soil may exist in forms that are not readily absorbed. At this site, the default relative bioavailability factor for lead of 0.60 has been applied.

As discussed previously, the primary mineral phases containing lead in the ten site soils which underwent speciation were found to be variable, specifically at high lead concentrations. This resulted in the inability to reliably estimate absorption fraction via comparison to tested samples. However, in order to evaluate the uncertainty surrounding use of the default factor (0.60), the site samples with the three highest lead concentrations (9,200 mg/kg, 5,700 mg/kg and 2,000 mg/kg) were compared to tested materials. The sample with the highest lead concentration (9,200 mg/kg) was found to most closely resemble the Jasper High Lead Smelter Sample. When tested in juvenile swine, this sample was found to have an absorption factor of 0.58, which is quite similar to EPA's default value. The second sample (5,700 mg/kg) was found be similar to two tested samples; Bingham Creek Channel and Butte. When tested in juvenile swine, these samples were found to have absorption factors of 0.28 and 0.19, respectively. The third sample (2,000 mg/kg) was the most similar to the remaining seven site samples, was judged to be most similar to the Bingham Creek Residential Composite sample. When tested in juvenile swine, this sample was found to have an absorption fraction of 0.31. As seen, there is a range of possible absorption factors possible for site soils. Based on these values, the use of the default factor of 0.60 is likely to be conservative, although further characterization of the soils would enable further evaluation of a site-specific absorption factor.

4.6 CONCLUSION

Based on the results of the IEUBK model, it is considered probable that lead levels in soil in this community are sufficiently high in a number of locations that there is risk that children will have elevated blood lead levels. Because direct measurements of blood lead levels in the community were not obtained, this model could be either over- or under-predicting actual risks. This model has been observed to overpredict risks to children from lead at several Western mining/smelting sites including; California Gulch, Sandy Smelter, Murray Smelter, Bingham Creek and Herriman. Therefore, it is more likely that risks are being overestimated rather than underestimated.

SECTION 5

SUMMARY AND CONCLUSIONS

5.1 RISKS FROM LEAD

Soils in the current residential area surrounding the Davenport and Flagstaff Smelters, are contaminated with relatively high levels of lead (estimated mean = 773 mg/kg, maximum = 27,000 mg/kg). Based on the results of the IEUBK model, it is considered probable that lead levels in soil in this community are sufficiently high in a number of locations that there is risk that children will have elevated blood lead levels.

5.2 RISKS FROM ARSENIC

Calculations suggest that arsenic in soil at the Davenport and Flagstaff Smelter site is likely to be within EPA's normal risk range for both average and RME residents.

SECTION 6

REFERENCES

ACGIH. 1995. American Conference of Governmental Industrial Hygenists, Inc. Lead, inorganic dust and fumes. Recommended BEI (7/24/95 draft).

ACGIH. 1998. American Conference of Governmental Industrial Hygenists, Inc. 1998 TLVs and BEIs - Threshold Limit Values for Chemical Substances and Chemical Agents. Arsenic, inorganic arsenic metabolites in urine. Recommended BEI.

ATSDR. 1991. Agency for Toxic Substances and Disease Registry. Toxicological profile for Arsenic. Atlanta, GA: Agency for Toxic Substances and Disease Registry.

CDC. 1991. Centers for Disease Control. Preventing lead poisoning in young children. A statement by the Centers of Disease Control - October. U.S. Department of Health and Human Services. Public Health Service.

Griffin S, Goodrum PE, Diamond GL, Meylan W, Brattin WJ, and Hassett JM. 1999a. Application of a probabilistic risk assessment methodology to a lead smelter site. Human and Ecological Risk Assessment. In Press.

Griffin S, Marcus A, Schulz T and Walker S. 1999b. Calculating the Inter-individual Geometric Standard Deviation for use in the Integrated Exposure Uptake Biokinetic Model for Lead in Children. Environmental Health Perspectives. 107(6):481-487.

IRIS. 1999. Retrieval from the USEPA Integrated Risk Information System (IRIS).

SRC. 1999. Syracuse Research Corporation. User's Guide for the Integrated Stochastic Exposure (ISE) Model for Lead. Prepared for ISSI Consulting Group, Inc. and USEPA Region VIII, June 30, 1999.

Sverdup Corporation. 1995. Uptake of Lead and Arsenic by Garden Vegetables, Study Report for the Kennecott Site. Prepared for USEPA. February 3, 1995. EPA Contract No. 68-W9-0032. Work Assignment No. 20-8BT8.

Tseng WP, Chu HM, How SW, et al. 1968. Prevalence of Skin Cancer in an Endemic Area of Chronic Arsenism in Taiwan. J. Natl. Cancer Inst. 40:453-463.

UDEQ. 1998. Utah Department of Environmental Quality, Division of Environmental Response and Remediation. Final Quality Assurance Project Plan for Davenport and Flagstaff Smelter – Site Characterization Study. October 12, 1998.

USEPA. 1984. U.S. Environmental Protection Agency, Office of Health and Environmental Assessment. Health Assessment Document for Inorganic Arsenic. Final

Report. Research Triangle Park, NC: U.S. Environmental protection Agency. EPA 600/8-83-021F.

USEPA. 1986. U.S. Environmental Protection Agency, Office of Health and Environmental Assessment. Air Quality Criteria for Lead. June, 1986, and Addendum, September, 1986. Research Triangle Park, NC: U.S. Environmental Protection Agency. EPA 600/8-83-028F.

USEPA. 1988a. U.S. Environmental Protection Agency, Office of Health and Environmental Assessment. Special Report of Ingested Inorganic Arsenic: Skin Cancer; Nutritional Essentiality. Washington, DC: U.S. Environmental Protection Agency. EPA/625/3-87/013.

USEPA. 1989a. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual (Part A). EPA Document EPA/540/1-89/002.

USEPA. 1989b. U.S. Environmental Protection Agency, Office of Health and Environmental Assessment. Evaluation of the Potential Carcinogenicity of Lead and Lead Compounds. EPA/60/8-89/045A.

USEPA. 1991a. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors". Washington, D.C. OSWER Directive 9285.6-03.

USEPA. 1991b. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions. Washington, D.C. OSWER Directive 9355.0-30.

USEPA. 1992a. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Supplemental Guidance to RAGS: Calculating the Concentration Term. EPA Publication No. 9285.7-081.

USEPA. 1992b. U.S. Environmental Protection Agency, Office of Research and Development. Dermal Exposure Assessment: Principles and Applications. Interim Report. Washington, D.C. EPA/600/8-91-011B.

USEPA. 1993. U.S. Environmental Protection Agency. Superfund's Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure. Draft, dated 11/04/93.

USEPA. 1994. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children. EPA Publication No. 9285.7-15-1.

USEPA. 1996. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Soil Screening Guidance: User's Guide. Washington, D.C. EPA Publication No. 9355.4-23. July 1996.

USEPA. 1997. U.S. Environmental Protection Agency. Policy for Use of Probabilistic Analysis in Risk Assessment at the U.S. Environmental Protection Agency. May 1997.

WESTON. 1997. Roy F. Weston, Inc. Relative Bioavailability of Arsenic in Mining Wastes. Prepared for U.S. Environmental Protection Agency, Region VIII. December 1997.

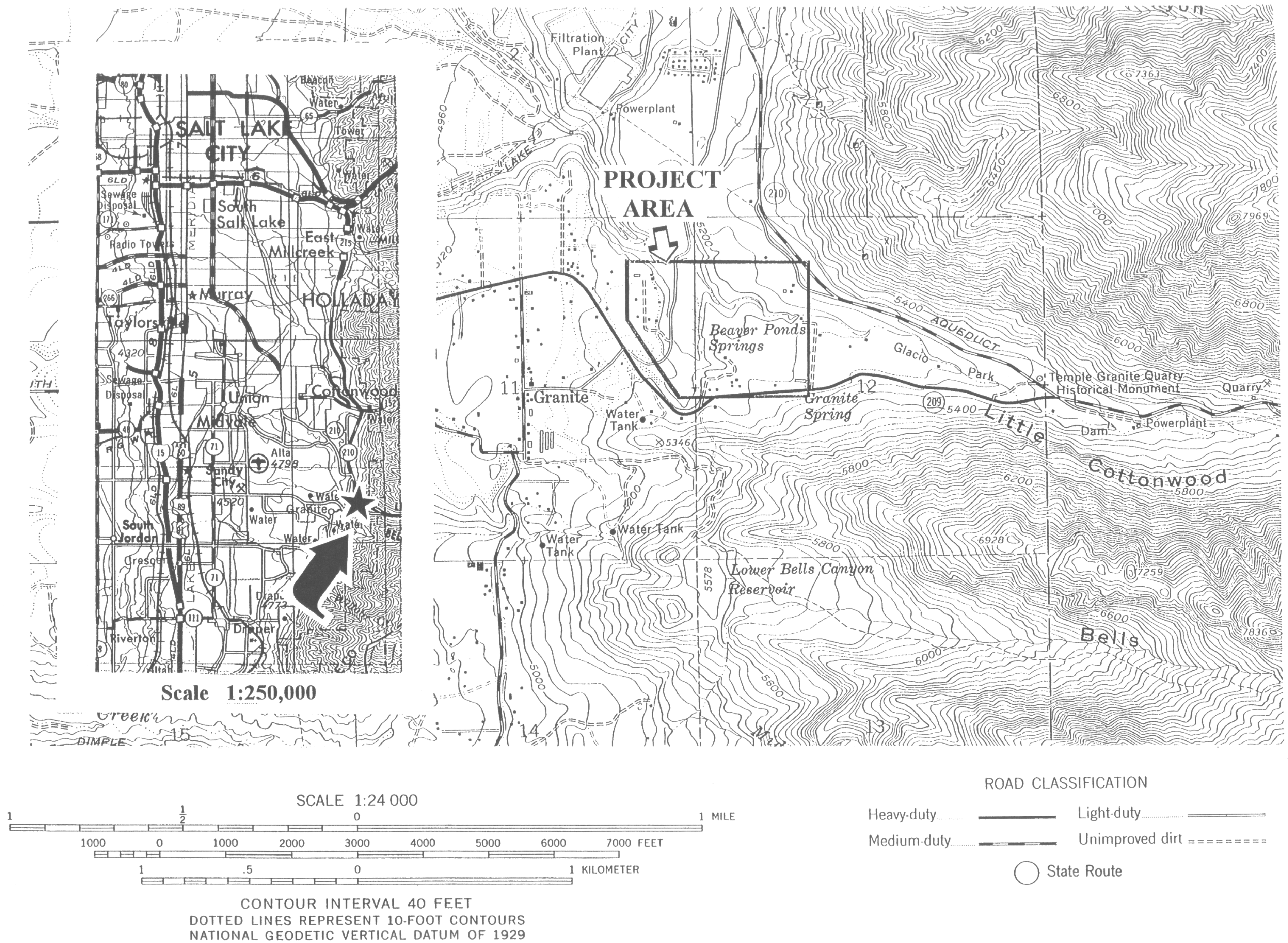


FIGURE 1-1 SITE MAP

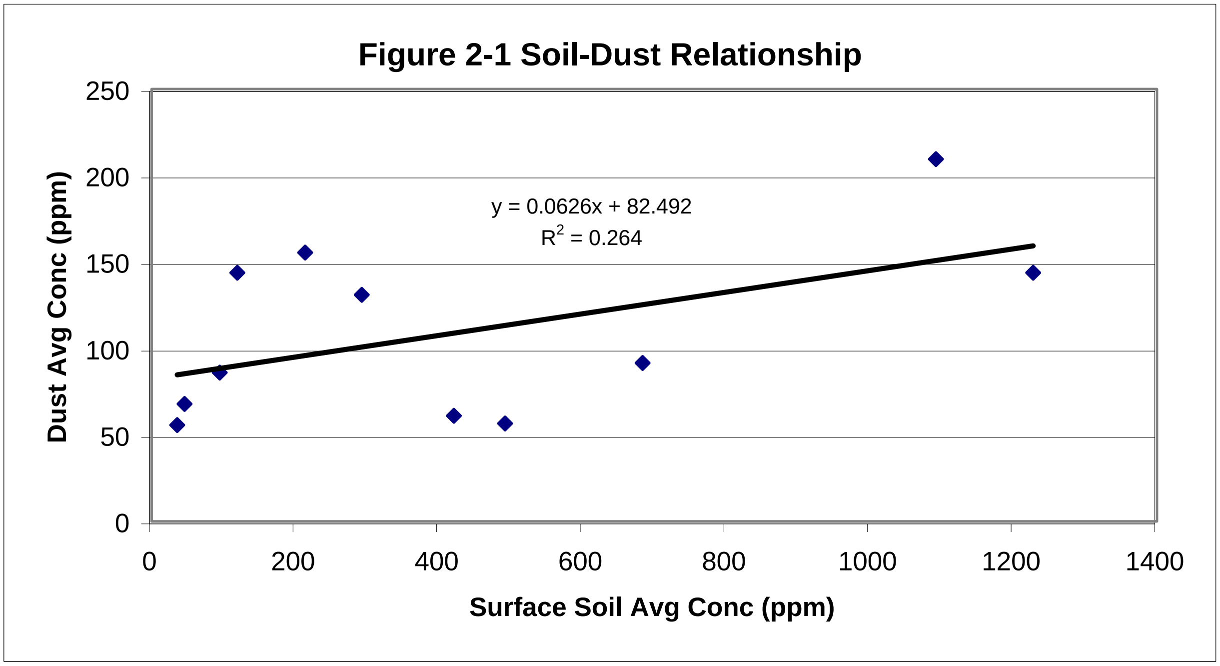


Figure 2-1 Soil-Dust Relationship
y = 0.0626x + 82.492
R2 = 0.264
Dust Avg Conc (ppm)
Surface Soil Avg Conc (ppm)
0
50
100
150
200
250
0
200
400
600
800
1000
1200
1400

TABLE 3-1 HUMAN EXPOSURE PARAMETERS

Scenario	Parameter	Value for Residents	
		Avg	RME
Ingestion of soil and dust	IR (total) as child (mg/day)	100	200
	IR (total) as adult (mg/day)	50	100
	Fraction of total that is soil	0.45	0.45
	BW (kg) as child	15	15
	BW (kg) as adult	70	70
	EF(d/yr)	234	350
	ED (yr) as child	2	6
	ED (yr) as adult	7	24
	ED (y) total	9	30
	AT (chronic) (years)	9	30
	AT (lifetime) (years)	70	70
HIF for Ingestion of Soil + Dust	Chronic (non-cancer)	1.31E-06	3.65E-06
	Lifetime (cancer)	1.68E-07	1.57E-06
HIF for Ingestion of Soil	Chronic (non-cancer)	5.88E-07	1.64E-06
	Lifetime (cancer)	7.56E-08	7.05E-07
HIF for Ingestion of Dust	Chronic (non-cancer)	7.18E-07	2.01E-06
	Lifetime (cancer)	9.23E-08	8.61E-07

Sources: USEPA 1989a, USEPA 1991a, USEPA 1993

TABLE 3-2 ARSENIC SPECIATION DATA FOR SAMPLES TESTED FOR IN VIVO BIOAVAILABILITY

ARSENIC SPECIATION DATA
MURRAY SMELTER SITE
SOIL SAMPLE

		Mean	LW Frequency			Relative As Mass			
PHASE	N	Size	Lib	Inc	Total	Lib	(% Lib)	Inc	Total
Fe-As Sulfate	1	35	0.24%		0.24%	5.80%	7.31%		5.80%
Slag	299	47	97.61%		97.61%	2.41%	3.04%		2.41%
PbMO	6	7	0.18%	0.10%	0.28%	0.24%	0.30%	0.13%	0.37%
PbAsO	44	5	1.24%	0.38%	1.62%	66.20%	83.48%	20.57%	86.77%
Fe-As Oxide	4	8	0.22%		0.22%	2.90%	3.66%		2.90%
AsMO	1	3	0.02%		0.02%	1.75%	2.20%		1.75%
Total	355		99.52%	0.48%	100.00%	79.30%	100.00%	20.70%	100.00%

ARSENIC SPECIATION DATA
MURRAY SMELTER SITE
SLAG SAMPLE

		Mean	LW Frequency			Rel As Mass			
Phase	N	Size	Lib	Inc	Total	Lib	(% Lib)	Inc	Total
SLAG	1037	17	98.61%		98.61%	13.91%	14.68%		13.91%
PbAsO	39	26	0.28%	0.03%	0.31%	43.69%	46.09%	5.08%	48.77%
Fe-As OXIDE	15	31	0.46%		0.46%	26.64%	28.10%		26.64%
Fe-As Sulfate	2	6	0.14%		0.14%	9.90%	10.44%		9.90%
PbMO	8	18	0.16%	0.03%	0.19%	0.62%	0.65%	0.12%	0.73%
Mn-As Oxide	7	73	0.28%		0.28%	0.04%	0.04%		0.04%
Total	1108		99.94%	0.06%	100.00%	94.80%	100.00%	5.20%	100.00%

ARSENIC SPECIATION DATA
MIDVALE SLAG SITE
SLAG SAMPLE

		Mean	LW Frequency			Relative As Mass			
PHASE	N	Size	Lib	Inc	Total	Lib	(% Lib)	Inc	Total
FeAs Oxide	4	26	0.04%		0.04%	0.15%	0.19%		0.15%
PbAs Oxide	119	16	0.62%	0.21%	0.83%	64.82%	83.51%	22.38%	87.20%
Slag	1721	131	99.09%		99.09%	11.25%	14.49%		11.25%
Sulfosalts	1	50	0.02%		0.02%	1.36%	1.75%		1.36%
FeAsSO4	2	15	0.01%		0.01%	0.04%	0.05%		0.04%
Total	1847		99.79%	0.21%	100.00%	77.62%	100.00%	22.38%	100.00%

ARSENIC SPECIATION DATA
CLARK FORK RIVER OU
GRANT KOHRS TAILINGS/SLICKENS SAMPLE

		Mean	LW Frequency			Relative As mass			
Phase	N	Size	Lib	Inc	Total	Lib	(% Lib)	Inc	Total
Fe-As Oxide	45	30	50.95%		53.51%	53.51%	57.15%		53.51%
Mn-As Oxide	7	20	5.20%		1.02%	1.02%	1.09%		1.02%
As Phosphate	20	25	18.06%	0.30%	15.66%	15.41%	16.46%	0.25%	15.66%
Slag	5	57	10.59%		0.10%	0.10%	0.11%		0.10%
Fe-As Sulfate	18	21	13.71%		16.65%	16.65%	17.78%		16.65%
Enargite	3	11	0.63%	0.56%	13.05%	6.93%	7.41%	6.12%	13.05%
Total	98		99.15%	0.85%	100.00%	93.63%	100.00%	6.37%	100.00%

ARSENIC SPECIATION DATA
CALIFORNIA GULCH SITE
AV SLAG SAMPLE

		Mean	LW Frequency			Relative As mass			
Phase	N	Size	Lib	Inc	Total	Lib	(% Lib)	Inc	Total
AsMO	2	35	0.05%		0.05%	5.20%	7.09%		5.20%
PbAsMO	37	5	0.07%	0.05%	0.12%	0.14%	0.18%	0.09%	0.22%
PbAsO	214	8	0.78%	0.36%	1.14%	57.80%	78.76%	26.35%	84.15%
PbMO	5	94	0.30%		0.30%	1.77%	2.41%		1.77%
PbMS	1	80	0.05%		0.05%	2.82%	3.85%		2.82%
PbMSO4	2	40	0.05%		0.05%	0.51%	0.69%		0.51%
Slag	1206	126	98.16%		98.16%	5.08%	6.92%		5.08%
Fe-As Sulfate	5	37	0.04%	0.08%	0.12%	0.08%	0.10%	0.18%	0.25%
Total	1472		99.51%	0.49%	100.00%	73.39%	100.00%	26.61%	100.00%

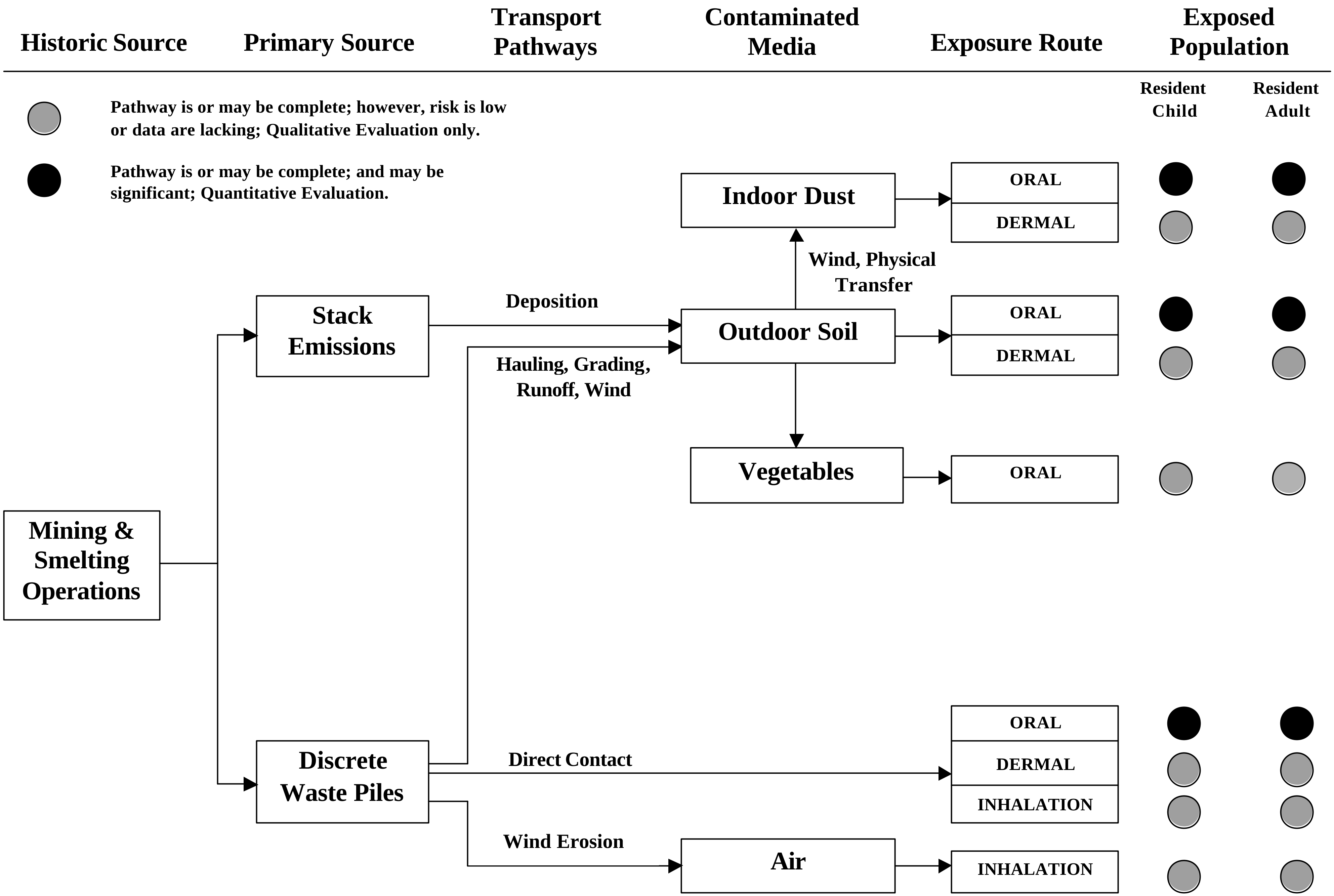


FIGURE 3-1 Conceptual Site Model for Residential Exposure to Arsenic

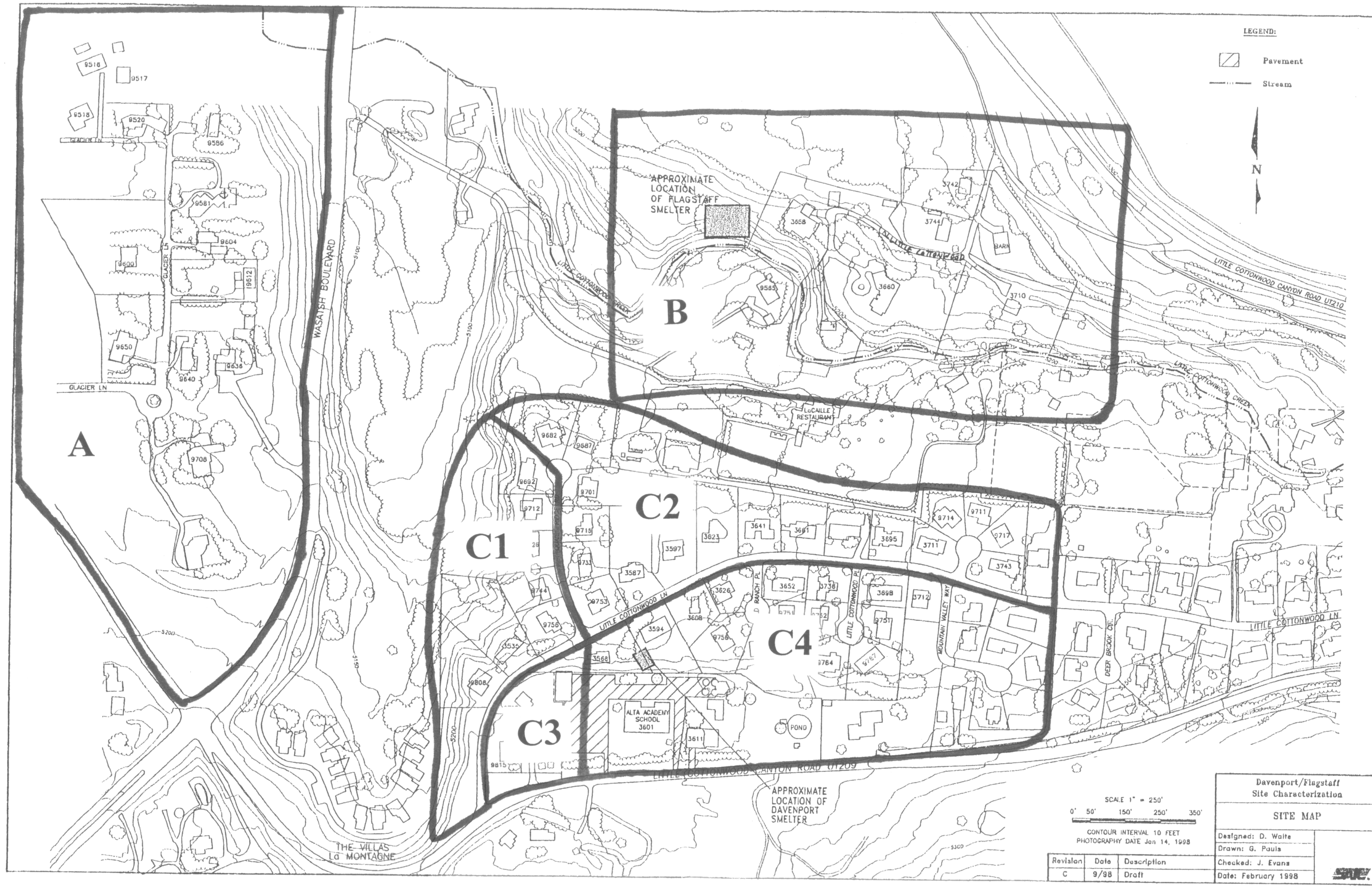


FIGURE 3-2 ZONE MAP

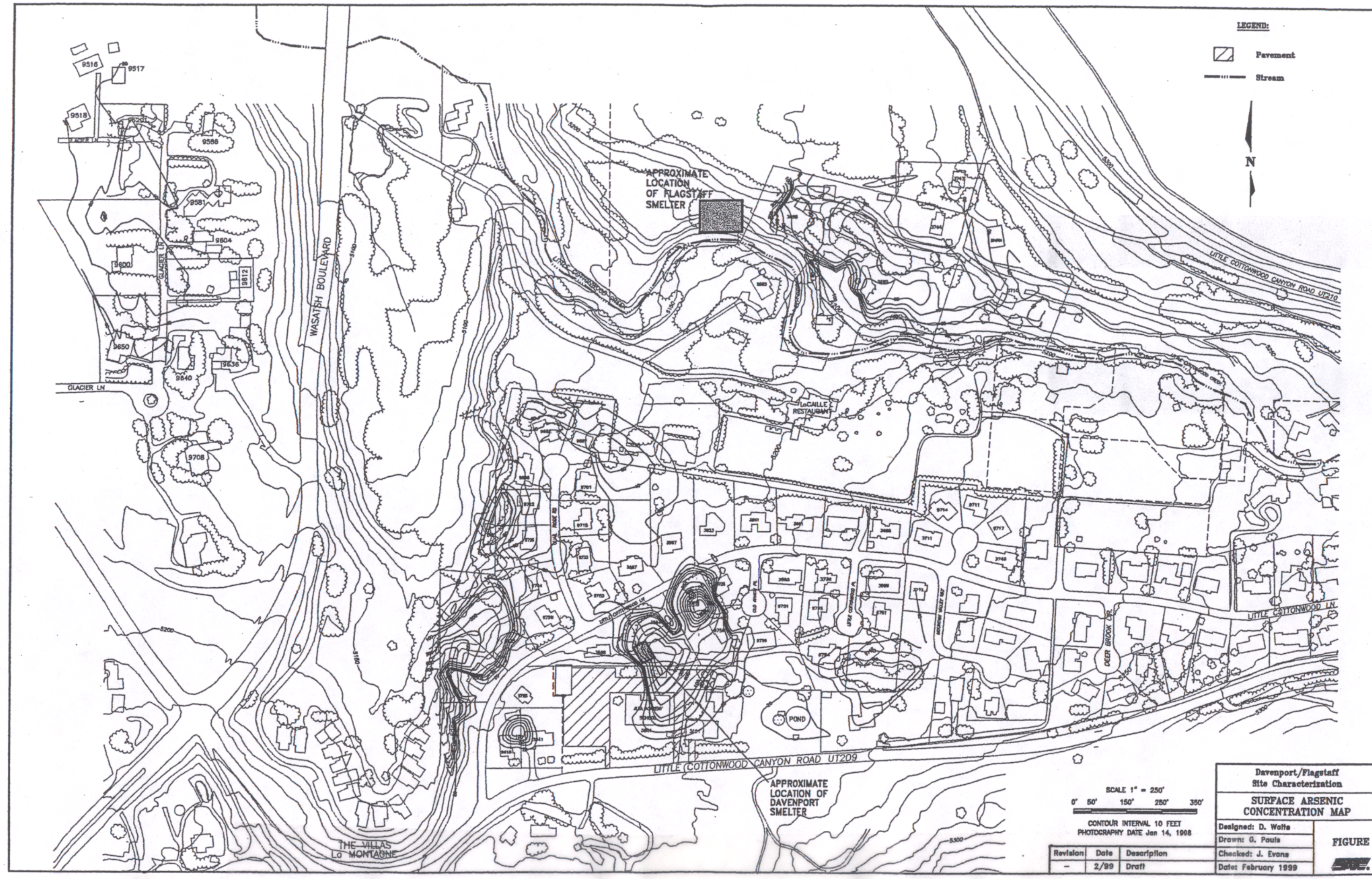
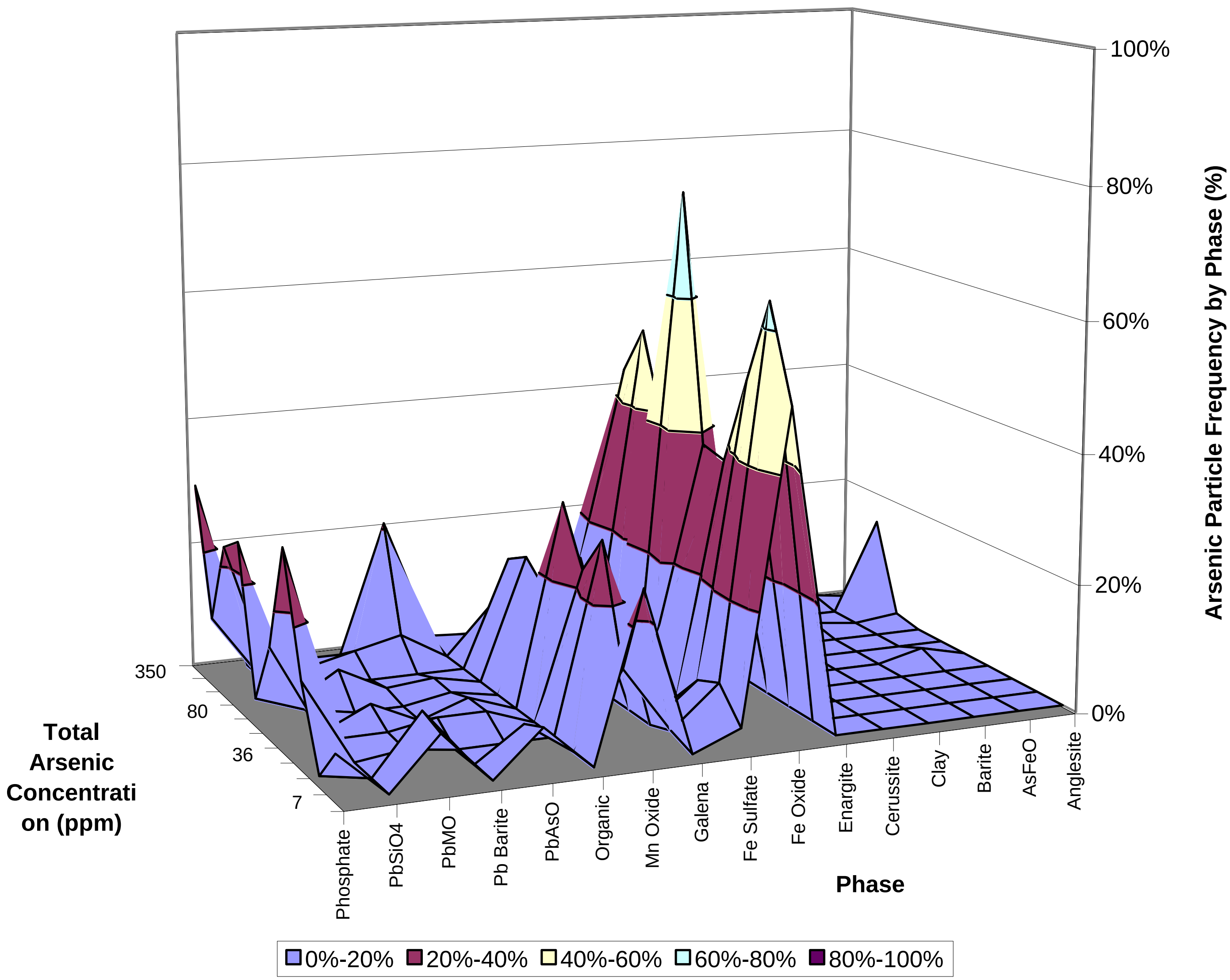


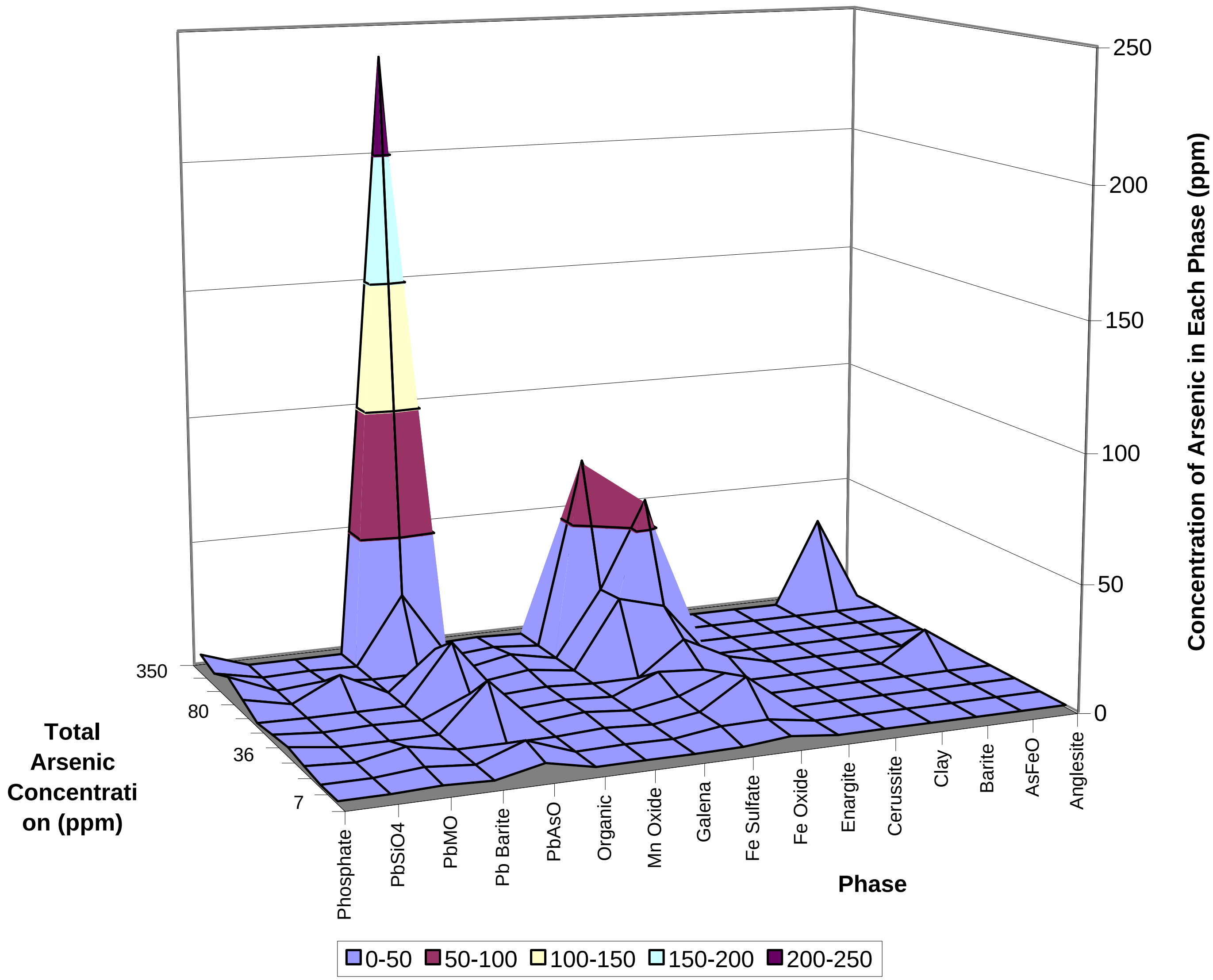
FIGURE 3-3 SITE SURFACE SOIL ARSENIC CONCENTRATIONS

Figure 3-4: Distribution of Arsenic Particle Frequency by Phase



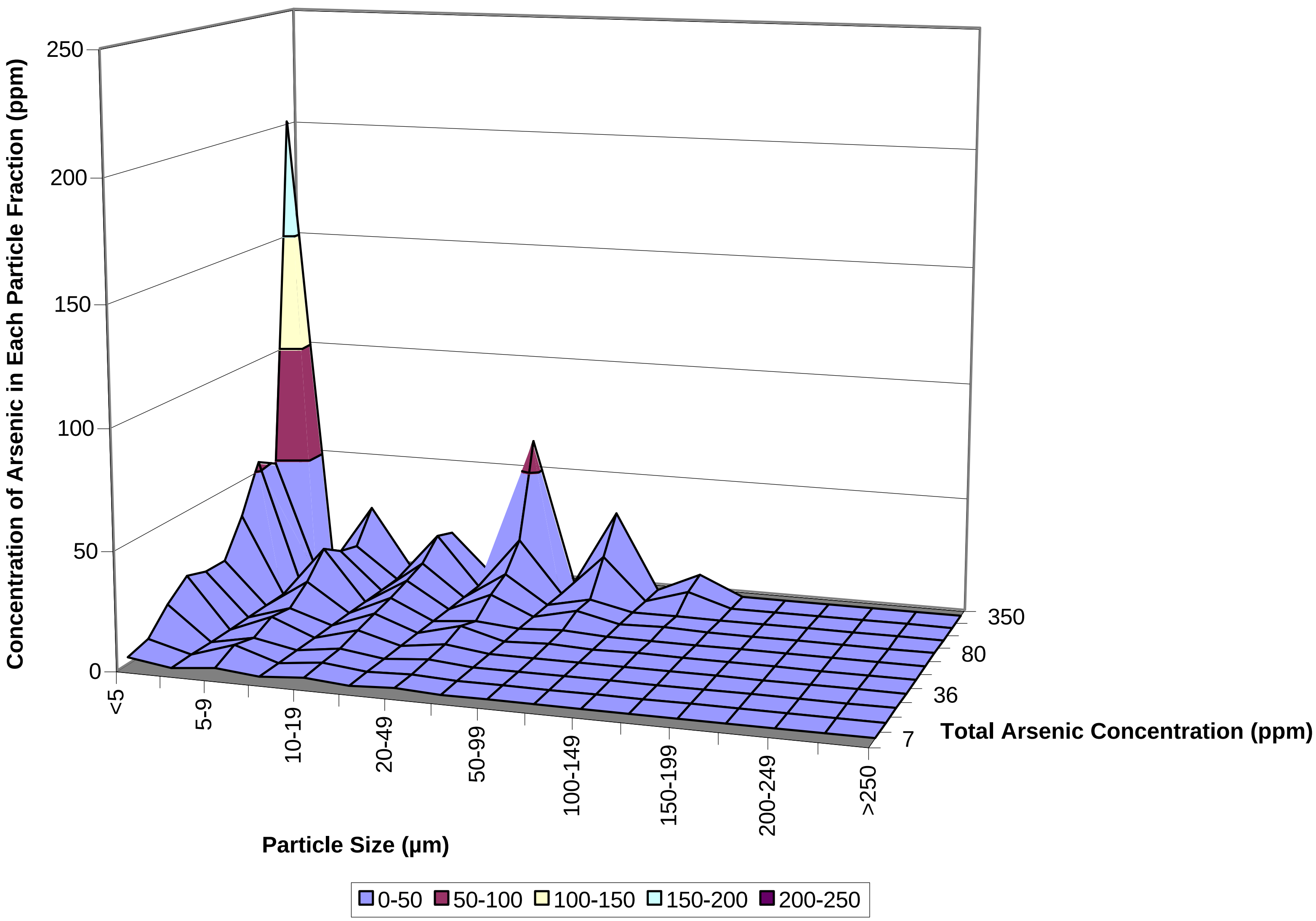
ParticleTypeAs_fsdv.xls

Figure 3-5: Distribution of Arsenic Mass by Phase



Asresults fsdv.xls

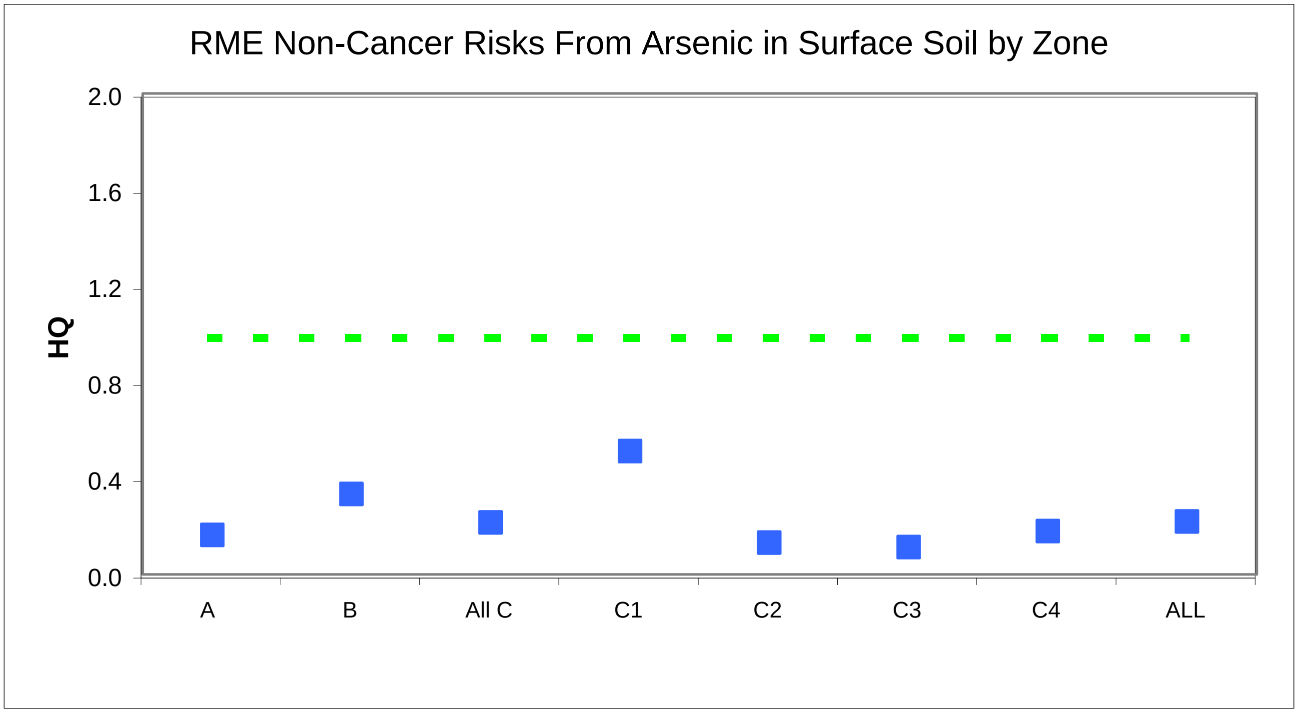
Figure 3-6: Distribution of Arsenic Mass by Particle Size

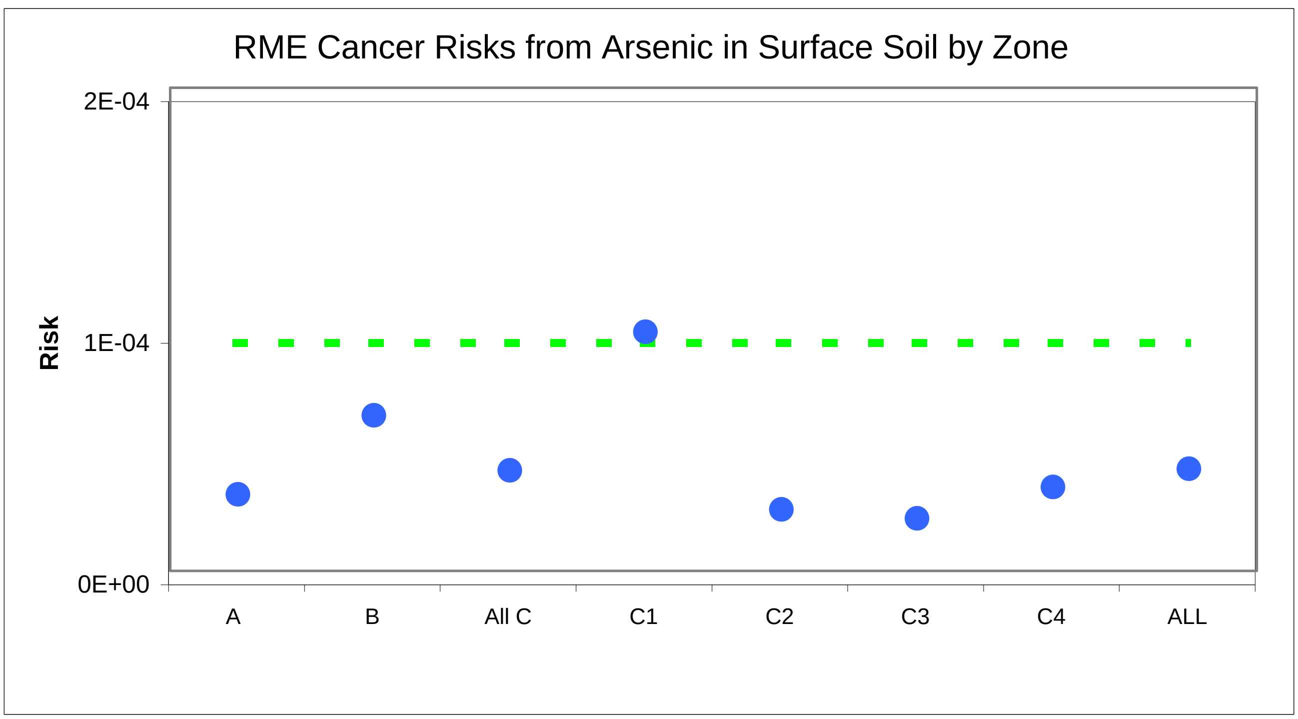


RelativeAsMass fsdv.xls

FIGURE 3-7 RISKS FROM ARSENIC BY ZONE

RBA = 0.51

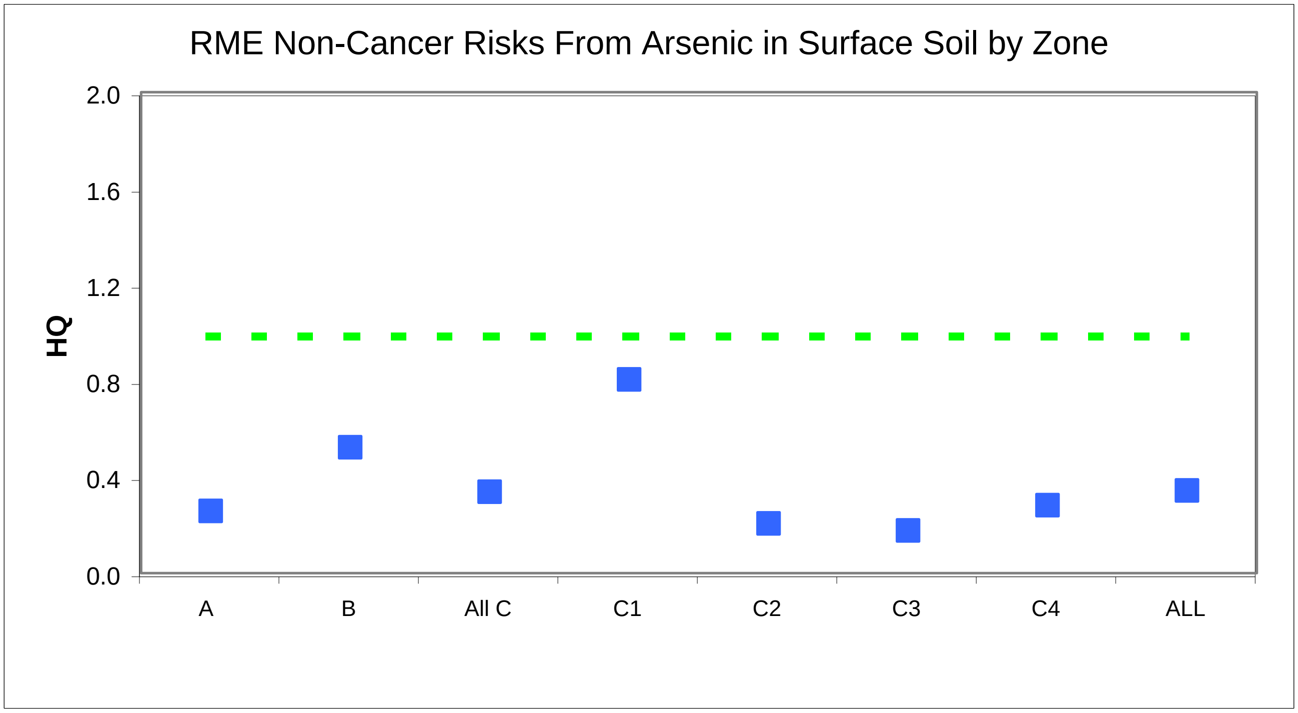


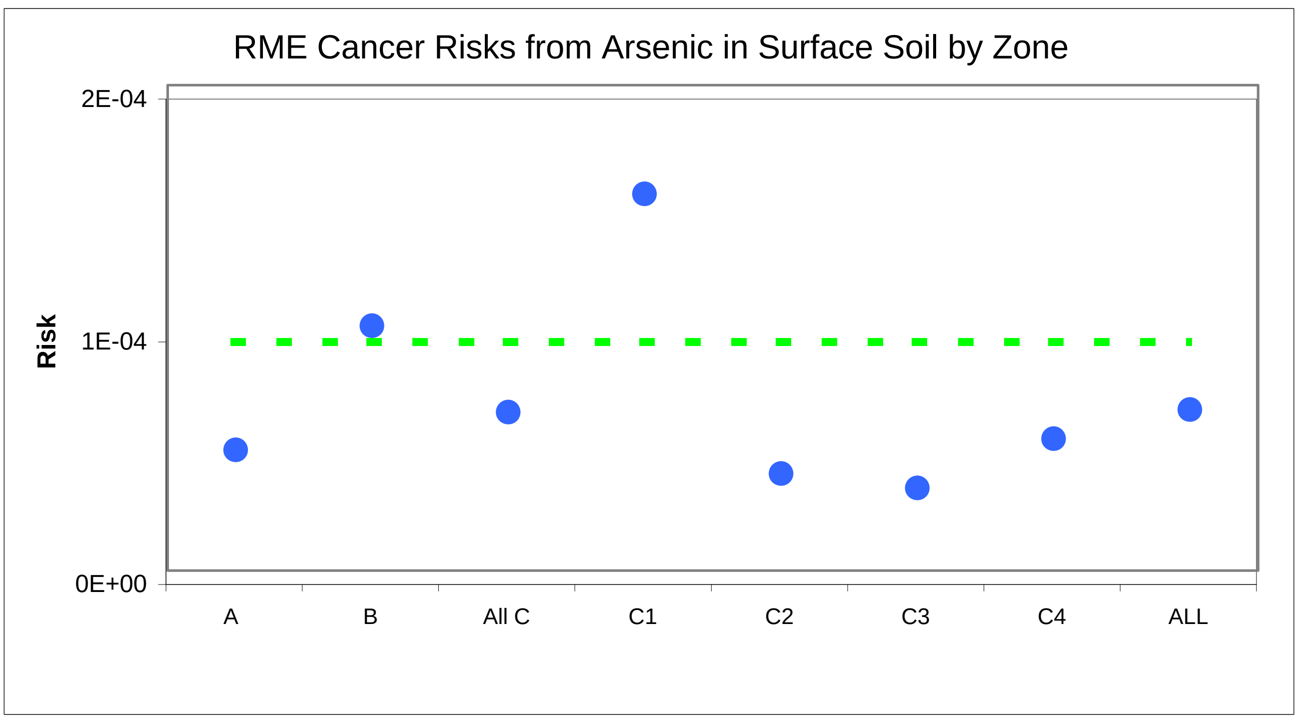


RISKCALC Arsenic.xls

FIGURE 3-8   RISKS FROM ARSENIC BY ZONE

RBA = 0.80





RISKCALC Arsenic RBA 80.xls

TABLE 4-1 RELATIVE LEAD MASS OF MINERAL PHASES FOR TEST MATERIALS EVALUATED FOR IN VIVO BIOAVAILABILITY

	Aspen		Bingham Creek		Butte	California Gulch Site				Jasper County			Midvale	Murray Smelter		Palmerton		Special Samples	
Phase	Residential	Berm	Creek Channel	Residential Composite	Soil	Phase I Res. Comp.	Fe/Mn PbO	AV Slag	Oregon Gulch	High Pb Smelter	High Pb Mill	Low Pb Yard	Slag Composite	Slag Composite	Soil Composite	Location 2	Location 4	NIST Paint	Galena + Soil
Al-Pb Silicate	0%	0.1%			0.1%														
Anglesite	1%	7%	28%		36%	10%		2%		1%	2%	0%		1.0%		6%	4%	1%	
Cerussite	64%	62%	0.3%	2%	0.3%	20%		1%		32%	57%	81%	4%	1.1%	14%			55%	
Fe-Pb Oxide	7%	9%	2%	5%	7%	6%	8%	51%		3%	2%	1%	0.3%			2%	2%		
Fe-Pb Silicate			0.3%	1%							1%	0.04%							
Galena	17%	12%	9%		12%	2%		3%	100%		3%	8%	6%	9%	20%				100%
Mn-Pb Oxide	5%	4%	2%	18%	20.2%	22%	72%			2%	9%	2%		0.8%		66%	66%		
Pb Organic	0.03%	0.03%	0.3%			0.11%	0.11%	1%											
Pb-As Oxide			1%	2%				31%				0.17%	33%	6%	29%				
Pb Oxide										0.09%	7%			69%	27%			44%	
Pb Barite	0%	0.06%	0.0%		0.007%	0.15%	0.14%				0.01%					1%	0.1%		
Pb Phosphate	1%	1%	26%	50%	3.6%	30%	15%			21%	7%	6%				24%	1%		
Fe-Pb Sulfate	5%	5%	30%	22%	20%	6%	3%	0.3%		3%	1%	1%	0.1%	0.3%	0.6%	1%			
PbO-Cerrusite						1%													
Slag						1%		10%		4%	1%		16%	7%	6%				
Clay							0.01%			0.018%	0.017%	0.003%				0.03%	0.13%		
PbSiO4						2%	0.8%												
Lead Vanidate						0.1%	0.4%										18%		
Fe Silicate										11%	8%	1%		1.5%					
Calcite										0.2%	0.1%								
Native Lead										22%	2%		15%	0.7%					
Sulfosalts													0.4%						
Pb(M)O													26%	4%	3%		7%		
ZN(M)SIO4														0.03%					
As(M)O															0.003%				
FE														0.04%	0.13%				
Zn-Pb Silicate																	2%		
PbSiO4																	1%		

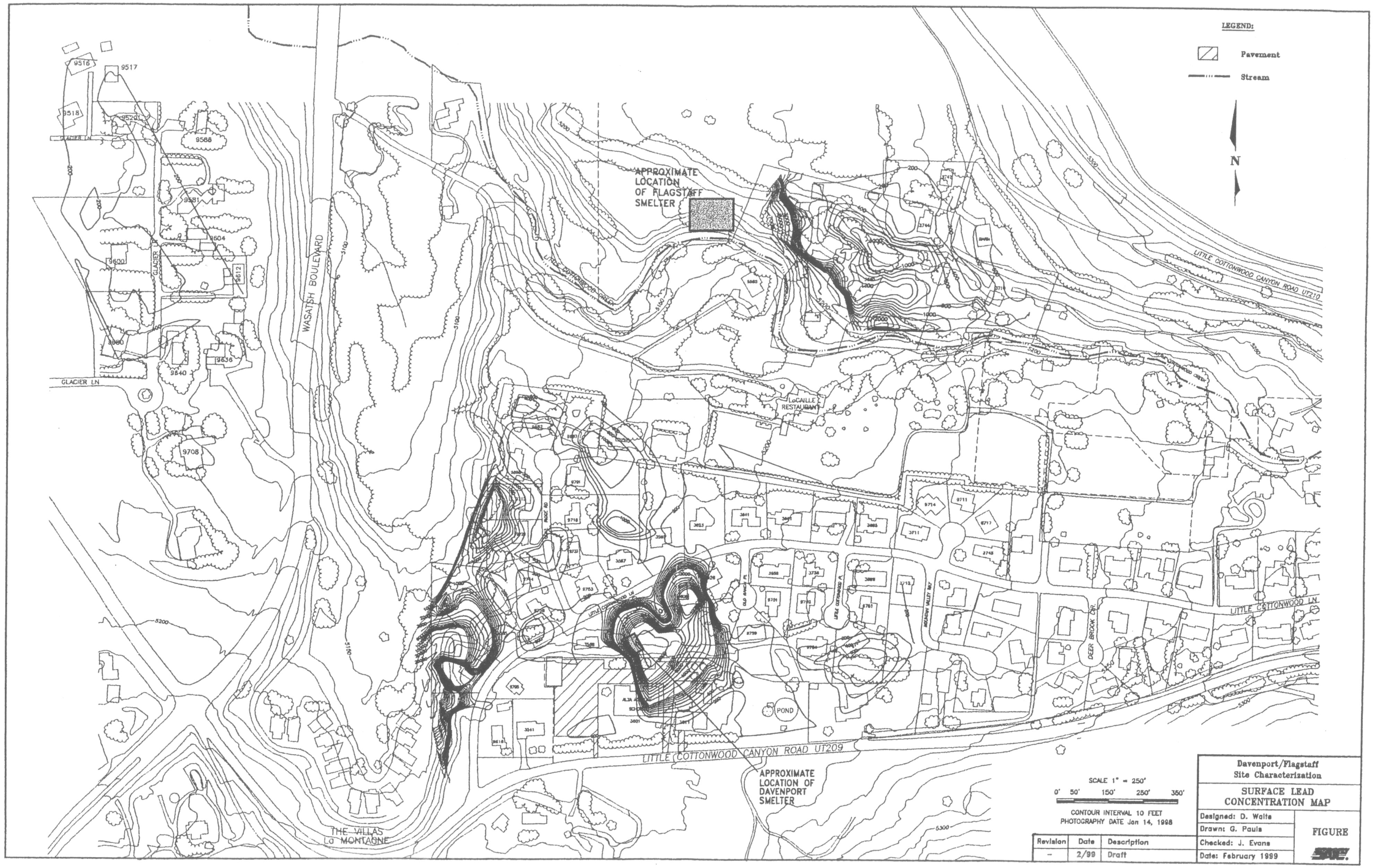
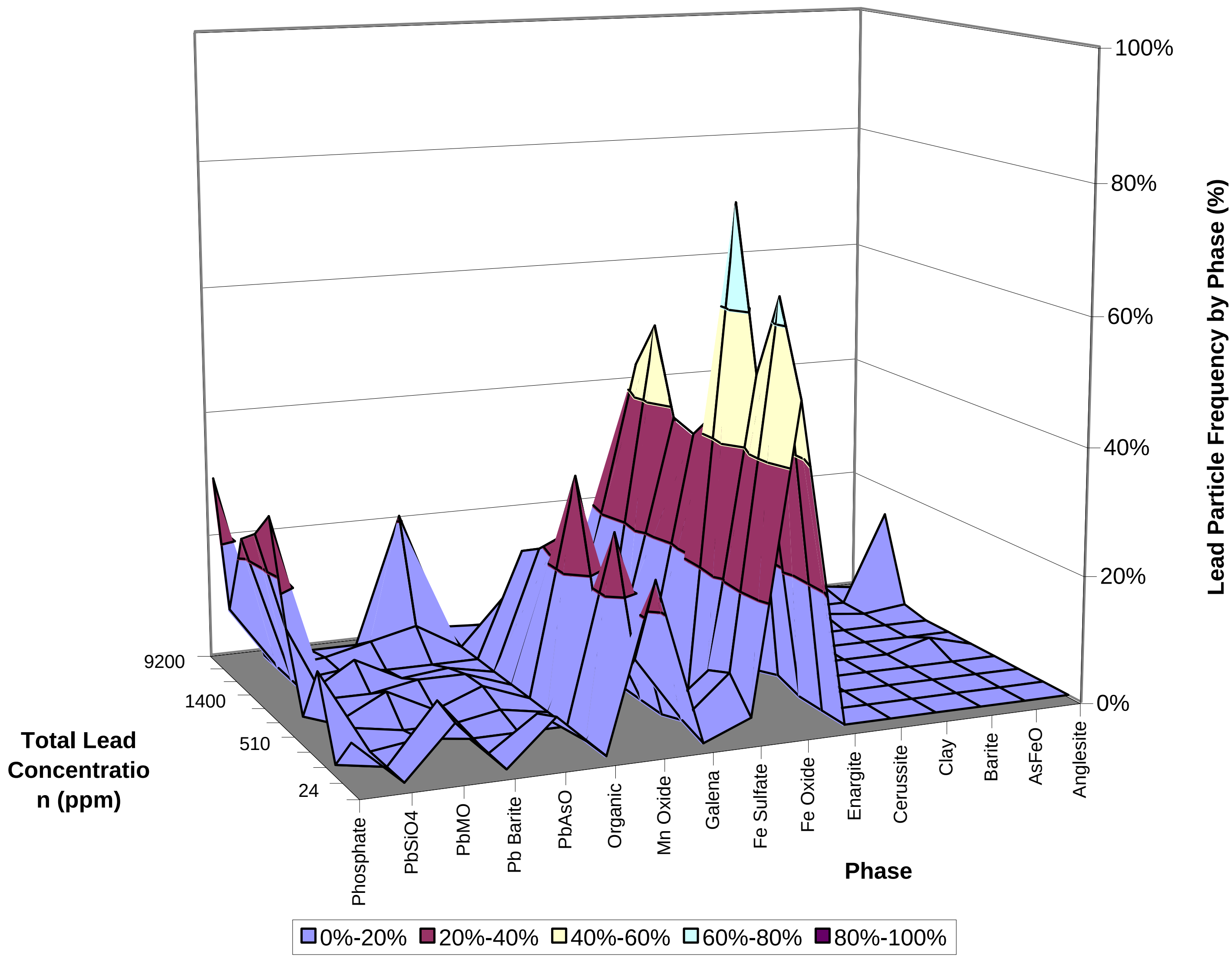


FIGURE 4-1 SITE SURFACE SOIL LEAD CONCENTRATIONS

Figure 4-2: Distribution of Lead Particle Frequency by Phase



ParticleTypePb_fsdv.xls

Figure 4-3: Distribution of Lead Mass by Phase

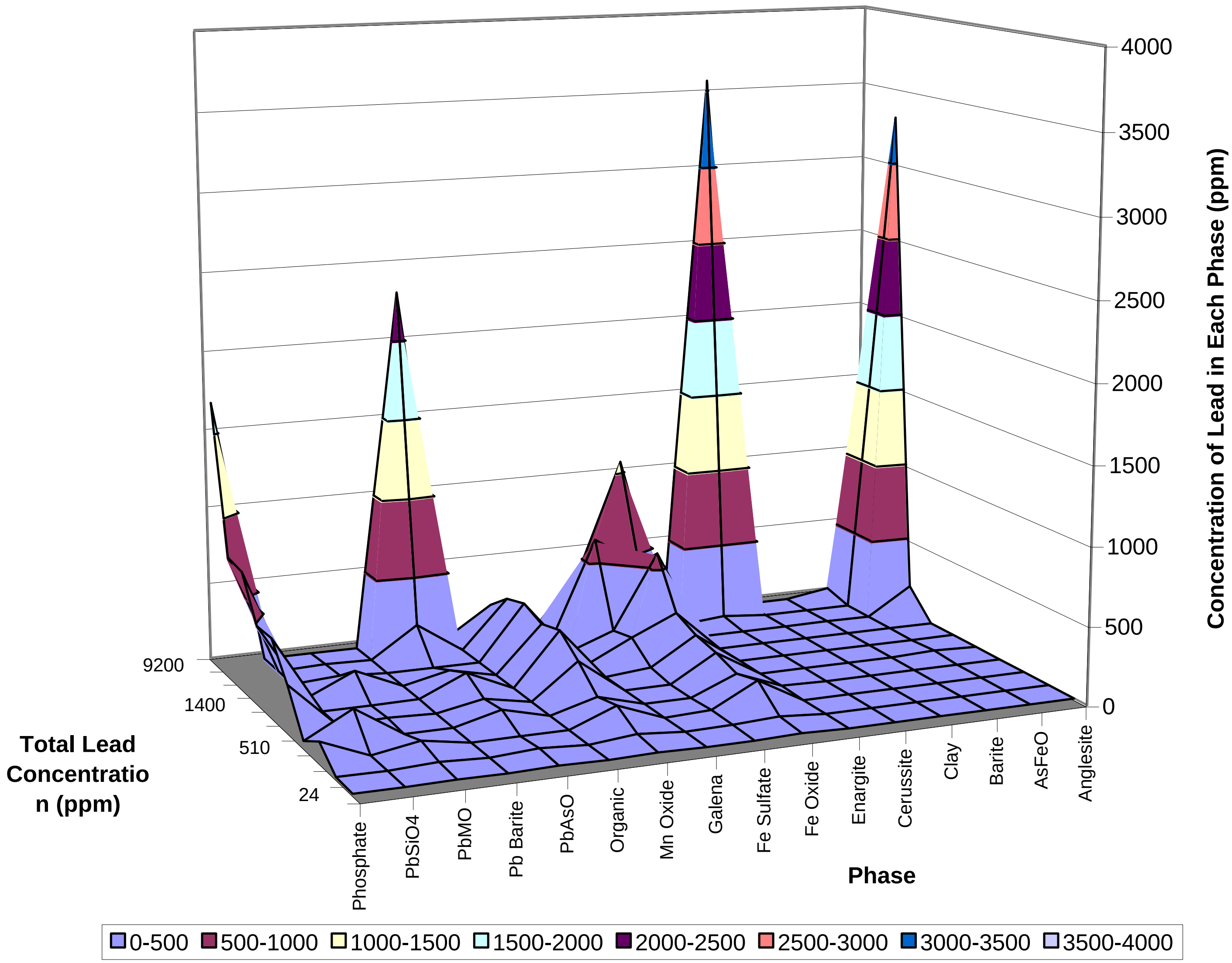
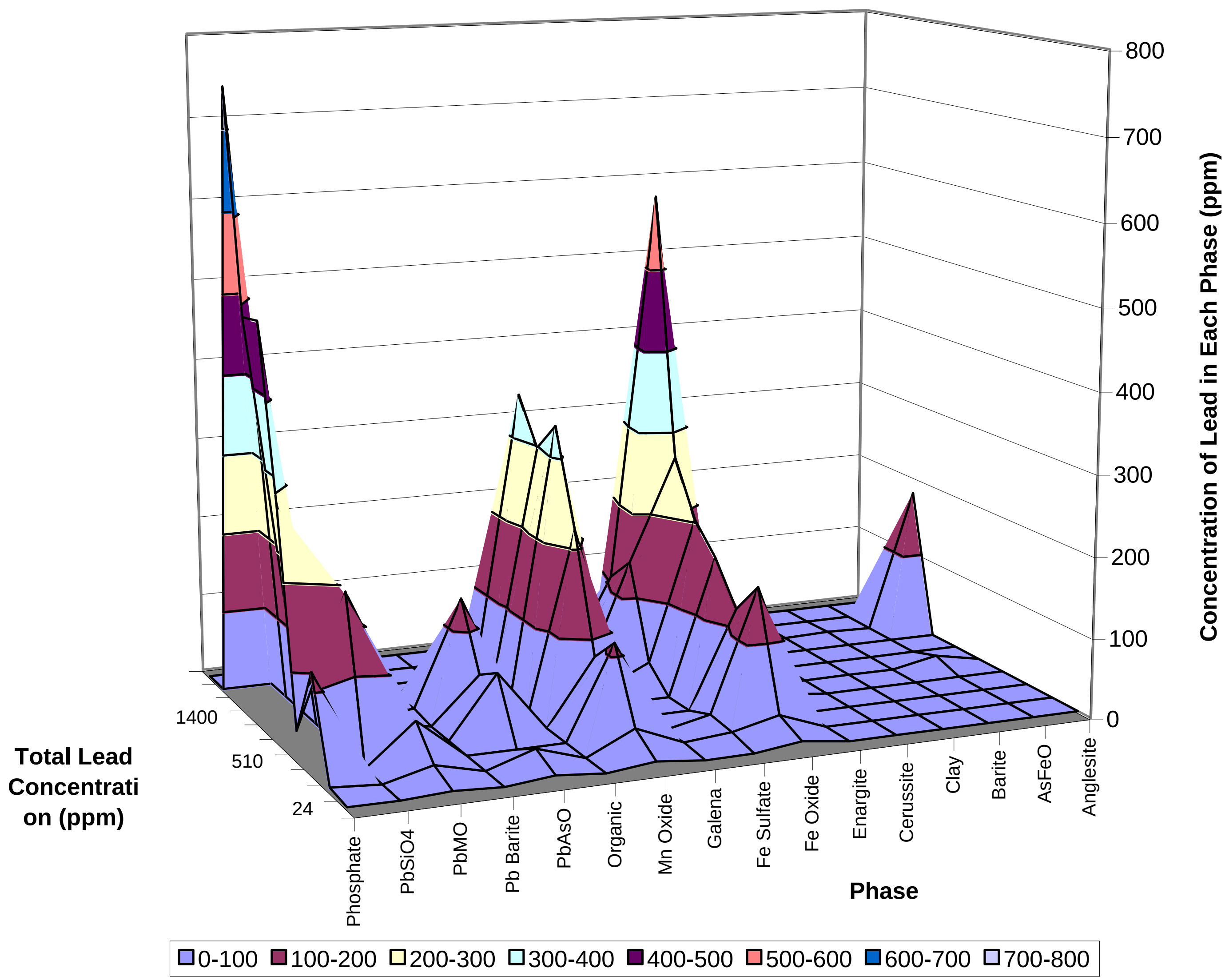
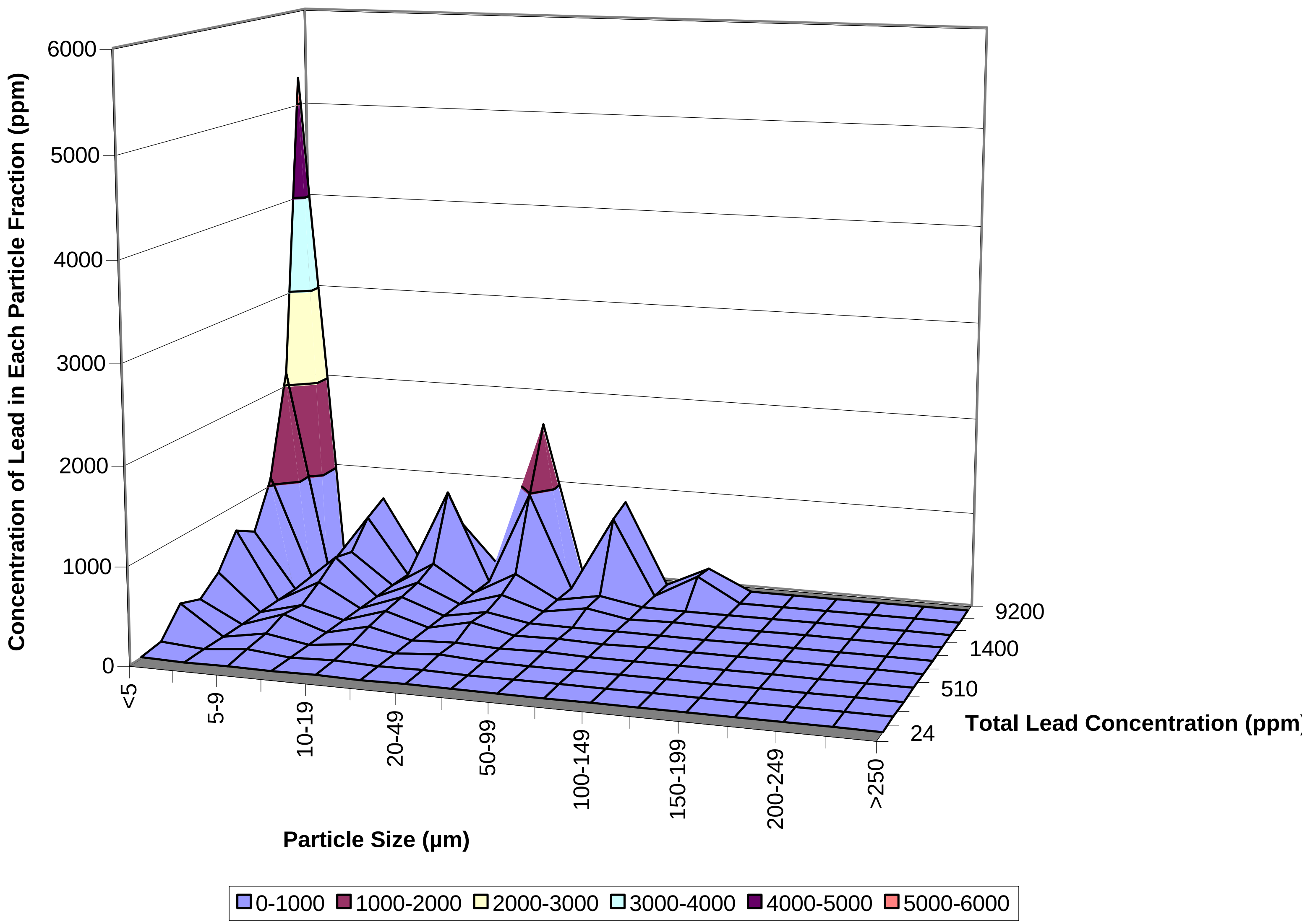


Figure 4-4: Distribution of Lead Mass by Phase



Pbresults fsdv part 2.xls

Figure 4-5: Distribution of Lead Mass by Particle Size



RelativePbMass fsdv.xls

10

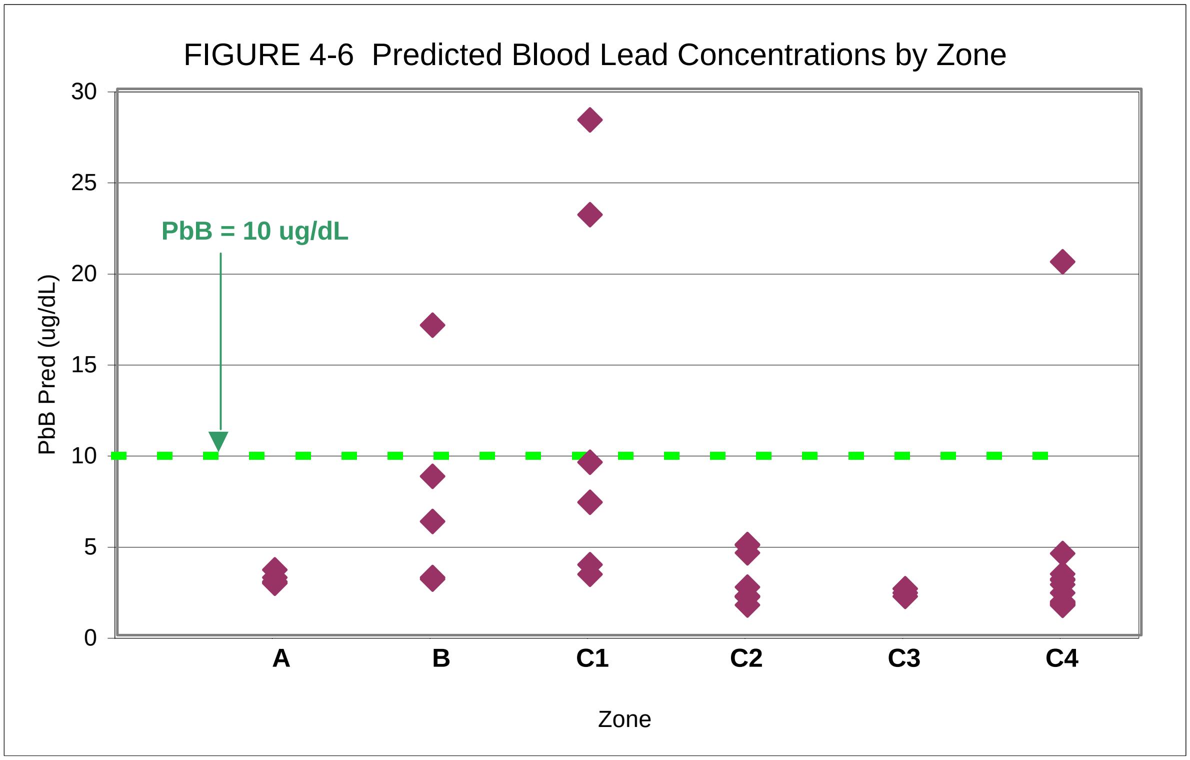


FIGURE 4-6 Predicted Blood Lead Concentrations by Zone
PbB = 10 ug/dL
PbB Pred (ug/dL)
30
25
20
15
10
5
0
A
B
C1
C2
C3
C4
Zone

APPENDIX 1 RAW DATA FOR SURFACE SOIL

Location	Sample Number	Depth	Zone	Lead (ppm)	Lead Q	Arsenic (ppm)	As Q
9650 Glacier Lane	0609-0-2"	0-2"	1	370		21	
9650 Glacier Lane	0610-0-2"	0-2"	2	440		64	
9650 Glacier Lane	0617-0-2"	0-2"	3	330		35	
9650 Glacier Lane	0618-0-2"	0-2"	4	250		24	
9650 Glacier Lane	0620-0-2"	0-2"	5	230		22	
9650 Glacier Lane	0621-0-2"	0-2"	6	160		16	
9650 Glacier Lane	0622-0-2"	0-2"	7	270		26	
9600 Glacier Lane	0633-0-2"	0-2"	1	210		22	
9600 Glacier Lane	0634-0-2"	0-2"	2	230		24	
9600 Glacier Lane	0635-0-2"	0-2"	3	200		23	
9600 Glacier Lane	0639-0-2"	0-2"	4	230		23	
9600 Glacier Lane	0640-0-2"	0-2"	5	160		17	
9600 Glacier Lane	0641-0-2"	0-2"	6	300		25	
9600 Glacier Lane	0642-0-2"	0-2"	7	180		16	
9600 Glacier Lane	0665-0-2"	0-2"	8	100		13	
9600 Glacier Lane	0666-0-2"	0-2"	9	100		14	
9600 Glacier Lane	0667-0-2"	0-2"	10	110		11	
9600 Glacier Lane	0668-0-2"	0-2"	11	410		28	
9600 Glacier Lane	0669-0-2"	0-2"	12	200		15	
9520 Glacier Lane	0687-0-2"	0-2"	1	150		58	
9520 Glacier Lane	0688-0-2"	0-2"	2	260		40	
9520 Glacier Lane	0689-0-2"	0-2"	3	79		12	
9520 Glacier Lane	0690-0-2"	0-2"	4	290		24	
9516 Glacier Lane	0697-0-2"	0-2"	1	190		15	
9516 Glacier Lane	0704-0-2"	0-2"	2	260		16	
9516 Glacier Lane	0705-0-2"	0-2"	3	120		15	
9516 Glacier Lane	0706-0-2"	0-2"	4	190		20	
9612 Glacier Lane	0726-0-2"	0-2"	1	270		25	
9612 Glacier Lane	0727-0-2"	0-2"	2	150		16	
9612 Glacier Lane	0728-0-2"	0-2"	3	240		21	
9612 Glacier Lane	0729-0-2"	0-2"	4	300		24	
9612 Glacier Lane	0730-0-2"	0-2"	5	200		19	
3601 Little Cottonwood Canyon Road (Alta Academy)	0778-0-2"	0-2"	1	89		12	
3601 Little Cottonwood Canyon Road (Alta Academy)	0779-0-2"	0-2"	2	120		14	
3601 Little Cottonwood Canyon Road (Alta Academy)	0780-0-2"	0-2"	3	320		18	
3601 Little Cottonwood Canyon Road (Alta Academy)	0787-0-2"	0-2"	4	110		13	
3601 Little Cottonwood Canyon Road (Alta Academy)	0788-0-2"	0-2"	5	110		14	
3601 Little Cottonwood Canyon Road (Alta Academy)	0795-0-2"	0-2"	6	130		11	
3601 Little Cottonwood Canyon Road (Alta Academy)	0800-0-2"	0-2"	7	150		11	
3601 Little Cottonwood Canyon Road (Alta Academy)	0804-0-2"	0-2"	8	240		14	
3601 Little Cottonwood Canyon Road (Alta Academy)	0805-0-2"	0-2"	9	760		37	
3601 Little Cottonwood Canyon Road (Alta Academy)	0812-0-2"	0-2"	10	330		17	
3601 Little Cottonwood Canyon Road (Alta Academy)	0813-0-2"	0-2"	11	360		20	
3601 Little Cottonwood Canyon Road (Alta Academy)	0814-0-2"	0-2"	12	220		16	
3601 Little Cottonwood Canyon Road (Alta Academy)	0834-0-2"	0-2"	13	360		30	
3601 Little Cottonwood Canyon Road (Alta Academy)	0835-0-2"	0-2"	14	240		23	
3601 Little Cottonwood Canyon Road (Alta Academy)	0836-0-2"	0-2"	15	66		9.8	
3601 Little Cottonwood Canyon Road (Alta Academy)	0838-0-2"	0-2"	16	66		11	
3601 Little Cottonwood Canyon Road (Alta Academy)	0845-0-2"	0-2"	17	79		12	
3601 Little Cottonwood Canyon Road (Alta Academy)	0847-0-2"	0-2"	18	100		14	
3541 Little Cottonwood Canyon Rd.	0879-0-2"	0-2"	1	110		8	
3541 Little Cottonwood Canyon Rd.	0880-0-2"	0-2"	2	110		10	
3541 Little Cottonwood Canyon Rd.	0884-0-2"	0-2"	3	120		8	
3541 Little Cottonwood Canyon Rd.	0885-0-2"	0-2"	4	140		17	
le Cottonwood Canyon Rd. S. E. Vacant Lot (South of Pa	0865-0-2"	0-2"	1	290		44	
le Cottonwood Canyon Rd. S. E. Vacant Lot (South of Pa	0866-0-2"	0-2"	2	230		26	
9767 Little Cottonwood Place	0764-0-2"	0-2"	1	24		7	
9767 Little Cottonwood Place	0765-0-2"	0-2"	2	510		37	
9767 Little Cottonwood Place	0766-0-2"	0-2"	3	780		70	
9767 Little Cottonwood Place	0767-0-2"	0-2"	4	610		70	
9767 Little Cottonwood Place	0768-0-2"	0-2"	5	180		17	
9751 Little Cottonwood Place	0018-0-2"	0-2"	1	24		8.4	
9751 Little Cottonwood Place	0020-0-2"	0-2"	2	38		14	
9751 Little Cottonwood Place	0022-0-2"	0-2"	3	82		15	
9751 Little Cottonwood Place	0023-0-2"	0-2"	4	89		19	

Location	Sample Number	Depth	Zone	Lead (ppm)	Lead Q	Arsenic (ppm)	As Q
9764 Little Cottonwood Place	0037-0-2"	0-2"	1	20		5.6	
9764 Little Cottonwood Place	0038-0-2"	0-2"	2	28		8.8	
9764 Little Cottonwood Place	0039-0-2"	0-2"	3	39		12	
9764 Little Cottonwood Place	0040-0-2"	0-2"	4	390		24	
9752 Little Cottonwood Place	0053-0-2"	0-2"	1	44		8	
9752 Little Cottonwood Place	0054-0-2"	0-2"	2	38		8	
9752 Little Cottonwood Place	0055-0-2"	0-2"	3	35		8	
9752 Little Cottonwood Place	0056-0-2"	0-2"	4	30		9	
Grow Park, Mountain Valley Way	0852-0-2"	0-2"	1	40		10	
Grow Park, Mountain Valley Way	0853-0-2"	0-2"	2	150		13	
Grow Park, Mountain Valley Way	0857-0-2"	0-2"	3	75		13	
Grow Park, Mountain Valley Way	0858-0-2"	0-2"	4	460		28	
3660 N. Little Cottonwood Road	0435-0-2"	0-2"	1	110		13	
3660 N. Little Cottonwood Road	0436-0-2"	0-2"	2	190		15	
3660 N. Little Cottonwood Road	0437-0-2"	0-2"	3	310		22	
3660 N. Little Cottonwood Road	0438-0-2"	0-2"	4	3000		130	
3660 N. Little Cottonwood Road	0440-0-2"	0-2"	5	1000		51	
3660 N. Little Cottonwood Road	0441-0-2"	0-2"	6	2900		140	
3660 N. Little Cottonwood Road	0442-0-2"	0-2"	7	2000		100	
3660 N. Little Cottonwood Road	0444-0-2"	0-2"	8	1400		53	
3660 N. Little Cottonwood Road	0445-0-2"	0-2"	9	63		9	
3660 N. Little Cottonwood Road	0449-0-2"	0-2"	10	73		10	
3660 N. Little Cottonwood Road	0450-0-2"	0-2"	11	130		12	
3660 N. Little Cottonwood Road	0451-0-2"	0-2"	12	2100		100	
3660 N. Little Cottonwood Road	0452-0-2"	0-2"	13	1500		67	
3660 N. Little Cottonwood Road	0453-0-2"	0-2"	14	1000		41	
3660 N. Little Cottonwood Road	0454-0-2"	0-2"	15	610		30	
3742 N. Little Cottonwood Road	0487-0-2"	0-2"	1	190		19	
3742 N. Little Cottonwood Road	0488-0-2"	0-2"	2	250		20	
3742 N. Little Cottonwood Road	0489-0-2"	0-2"	3	270		20	
3742 N. Little Cottonwood Road	0490-0-2"	0-2"	4	270		20	
3742 N. Little Cottonwood Road	0491-0-2"	0-2"	5	190		15	
3710 N. Little Cottonwood Road	0524-0-2"	0-2"	1	200		15	
3710 N. Little Cottonwood Road	0531-0-2"	0-2"	2	470		28	
3710 N. Little Cottonwood Road	0532-0-2"	0-2"	3	750		49	
3710 N. Little Cottonwood Road	0537-0-2"	0-2"	4	460		30	
3710 N. Little Cottonwood Road	0538-0-2"	0-2"	5	540		28	
3710 N. Little Cottonwood Road	0539-0-2"	0-2"	6	760		54	
3710 N. Little Cottonwood Road	0540-0-2"	0-2"	7	500		45	
3710 N. Little Cottonwood Road	0541-0-2"	0-2"	8	980		60	
3710 N. Little Cottonwood Road	0543-0-2"	0-2"	9	840		57	
3710 N. Little Cottonwood Road	0544-0-2"	0-2"	10	1200		72	
3710 N. Little Cottonwood Road	0545-0-2"	0-2"	11	820		41	
3656 N. Little Cottonwood Road	0552-0-2"	0-2"	1	420		19	
3656 N. Little Cottonwood Road	0553-0-2"	0-2"	2	790		34	
3656 N. Little Cottonwood Road	0554-0-2"	0-2"	3	300		16	
3656 N. Little Cottonwood Road	0557-0-2"	0-2"	4	260		18	
3656 N. Little Cottonwood Road	0558-0-2"	0-2"	5	1000		54	
3656 N. Little Cottonwood Road	0559-0-2"	0-2"	6	9200		350	
3656 N. Little Cottonwood Road	0564-0-2"	0-2"	7	7700		370	
3744 N. Little Cottonwood Road	0584-0-2"	0-2"	1	180		14	
3744 N. Little Cottonwood Road	0585-0-2"	0-2"	2	310		15	
3744 N. Little Cottonwood Road	0586-0-2"	0-2"	3	140		14	
3744 N. Little Cottonwood Road	0587-0-2"	0-2"	4	250		13	
9756 Old Ranch Place	0143-0-2"	0-2"	1	25		5	U
9756 Old Ranch Place	0144-0-2"	0-2"	2	8800		190	
9756 Old Ranch Place	0145-0-2"	0-2"	3	2800		190	
9756 Old Ranch Place	0153-0-2"	0-2"	4	1300		76	
9756 Old Ranch Place	0157-0-2"	0-2"	5	5700		130	
9759 Old Ranch Place	0322-0-2"	0-2"	1	69		10	
9759 Old Ranch Place	0334-0-2"	0-2"	2	270		20	
9759 Old Ranch Place	0335-0-2"	0-2"	3	240		12	
9759 Old Ranch Place	0336-0-2"	0-2"	4	410		17	
9759 Old Ranch Place	0338-0-2"	0-2"	5	120		11	
9751 Old Ranch Place	0352-0-2"	0-2"	1	23		9	

Location	Sample Number	Depth	Zone	Lead (ppm)	Lead Q	Arsenic (ppm)	As Q
9751 Old Ranch Place	0353-0-2"	0-2"	2	34		10	
9751 Old Ranch Place	0354-0-2"	0-2"	3	30		12	
9751 Old Ranch Place	0355-0-2"	0-2"	4	30		13	
9687 Quail Ridge Road	0194-0-2"	0-2"	1	120		10	
9687 Quail Ridge Road	0196-0-2"	0-2"	2	440		20	
9687 Quail Ridge Road	0200-0-2"	0-2"	3	390		19	
9687 Quail Ridge Road	0201-0-2"	0-2"	4	1100		32	
9687 Quail Ridge Road	0202-0-2"	0-2"	5	410		18	
9682 Quail Ridge Road	0209-0-2"	0-2"	1	51		11	
9682 Quail Ridge Road	0214-0-2"	0-2"	2	59		9	
9682 Quail Ridge Road	0215-0-2"	0-2"	3	460		22	
9682 Quail Ridge Road	0216-0-2"	0-2"	4	380		23	
9682 Quail Ridge Road	0217-0-2"	0-2"	5	670		37	
9682 Quail Ridge Road	0218-0-2"	0-2"	6	930		39	
9712 Quail Ridge Road	0231-0-2"	0-2"	1	370		10	
9712 Quail Ridge Road	0232-0-2"	0-2"	2	640		23	
9712 Quail Ridge Road	0233-0-2"	0-2"	3	1400		80	
9712 Quail Ridge Road	0234-0-2"	0-2"	4	2500		81	
9715 Quail Ridge Road	0245-0-2"	0-2"	1	12		6	
9715 Quail Ridge Road	0246-0-2"	0-2"	3	30		10	
9715 Quail Ridge Road	0247-0-2"	0-2"	2	43		11	
9715 Quail Ridge Road	0248-0-2"	0-2"	4	55		11	
9715 Quail Ridge Road	0249-0-2"	0-2"	5	27		7	
9756 Quail Ridge Road	0265-0-2"	0-2"	1	94		10	
9756 Quail Ridge Road	0266-0-2"	0-2"	2	46		10	
9756 Quail Ridge Road	0267-0-2"	0-2"	3	790		24	
9756 Quail Ridge Road	0268-0-2"	0-2"	4	100		14	
9753 Quail Ridge Road	0282-0-2"	0-2"	1	150		10	
9753 Quail Ridge Road	0283-0-2"	0-2"	2	230		18	
9753 Quail Ridge Road	0284-0-2"	0-2"	3	60		10	
9753 Quail Ridge Road	0285-0-2"	0-2"	4	200		18	
9696 Quail Ridge Road	0302-0-2"	0-2"	1	78		29	
9696 Quail Ridge Road	0303-0-2"	0-2"	2	130		14	
9696 Quail Ridge Road	0304-0-2"	0-2"	3	450		32	
9696 Quail Ridge Road	0305-0-2"	0-2"	4	670		36	
9726 Quail Ridge Road	0740-0-2"	0-2"	1	91		11	
9726 Quail Ridge Road	0741-0-2"	0-2"	2	710		28	
9726 Quail Ridge Road	0742-0-2"	0-2"	3	610		37	
9726 Quail Ridge Road	0744-0-2"	0-2"	4	2000		83	
3698 Little Cottonwood Lane	0002-0-2"	0-2"	1	34		9.6	
3698 Little Cottonwood Lane	0003-0-2"	0-2"	2	27		7.8	
3698 Little Cottonwood Lane	0004-0-2"	0-2"	3	34		13	
3698 Little Cottonwood Lane	0005-0-2"	0-2"	4	48		12	
3695 Little Cottonwood Lane	0070-0-2"	0-2"	1	72		12	
3695 Little Cottonwood Lane	0071-0-2"	0-2"	2	48		8	
3695 Little Cottonwood Lane	0072-0-2"	0-2"	3	120		14	
3695 Little Cottonwood Lane	0073-0-2"	0-2"	4	140		15	
3641 Little Cottonwood Lane	0086-0-2"	0-2"	1	58		13	
3641 Little Cottonwood Lane	0087-0-2"	0-2"	2	54		8	
3641 Little Cottonwood Lane	0088-0-2"	0-2"	3	85		13	
3641 Little Cottonwood Lane	0089-0-2"	0-2"	4	160		15	
3652 Little Cottonwood Lane	0103-0-2"	0-2"	1	42		11	
3652 Little Cottonwood Lane	0104-0-2"	0-2"	2	64		12	
3652 Little Cottonwood Lane	0112-0-2"	0-2"	3	54		15	
3652 Little Cottonwood Lane	0113-0-2"	0-2"	4	36		12	
3626 Little Cottonwood Lane	0120-0-2"	0-2"	1	45		7	
3626 Little Cottonwood Lane	0121-0-2"	0-2"	2	46		6	
3626 Little Cottonwood Lane	0126-0-2"	0-2"	3	29		9	
3626 Little Cottonwood Lane	0127-0-2"	0-2"	4	63		11	
3623 Little Cottonwood Lane	0177-0-2"	0-2"	1	35		5	
3623 Little Cottonwood Lane	0178-0-2"	0-2"	2	88		7	
3623 Little Cottonwood Lane	0179-0-2"	0-2"	3	140		10	
3623 Little Cottonwood Lane	0180-0-2"	0-2"	4	130		9	
3623 Little Cottonwood Lane	0181-0-2"	0-2"	5	69		6	
9795 Little Cottonwood Lane	0368-0-2"	0-2"	1	100		11	

Location	Sample Number	Depth	Zone	Lead (ppm)	Lead Q	Arsenic (ppm)	As Q
9795 Little Cottonwood Lane	0369-0-2"	0-2"	2	130		13	
9795 Little Cottonwood Lane	0370-0-2"	0-2"	3	56		7	
9795 Little Cottonwood Lane	0371-0-2"	0-2"	4	91		9	
9808 Little Cottonwood Lane	0382-0-2"	0-2"	1	92		12	
9808 Little Cottonwood Lane	0383-0-2"	0-2"	2	990		33	
9808 Little Cottonwood Lane	0384-0-2"	0-2"	3	1600		63	
9808 Little Cottonwood Lane	0385-0-2"	0-2"	4	24000		550	
9808 Little Cottonwood Lane	0386-0-2"	0-2"	5	4600		120	
9815 Little Cottonwood Lane	0406-0-2"	0-2"	1	100		11	
9815 Little Cottonwood Lane	0407-0-2"	0-2"	2	170		10	
9815 Little Cottonwood Lane	0408-0-2"	0-2"	3	190		14	
9815 Little Cottonwood Lane	0409-0-2"	0-2"	4	140		10	
Slope on Little Cottonwood Lane	0893-0-2"	0-2"	1	390		23	
Slope on Little Cottonwood Lane	0897-0-2"	0-2"	2	540		32	
Slope on Little Cottonwood Lane	0901-0-2"	0-2"	3	370		19	
Slope on Little Cottonwood Lane	0902-0-2"	0-2"	4	440		19	
Slope on Little Cottonwood Lane	0903-0-2"	0-2"	5	750		28	
Slope on Little Cottonwood Lane	0914-0-2"	0-2"	6	3000		78	
Slope on Little Cottonwood Lane	0918-0-2"	0-2"	7	27000		650	
Slope on Little Cottonwood Lane	0922-0-2"	0-2"	8	3400		94	
3587 Little Cottonwood Lane	0929-0-2"	0-2"	1	57		7.7	
3587 Little Cottonwood Lane	0930-0-2"	0-2"	2	240		14	
3587 Little Cottonwood Lane	0931-0-2"	0-2"	3	1200		36	
3587 Little Cottonwood Lane	0932-0-2"	0-2"	4	760		27	
3587 Little Cottonwood Lane	0933-0-2"	0-2"	5	180		12	

APPENDIX 2 RAW DATA FOR SUBSURFACE SOIL

Location	Sample Number	Depth	Zone	Lead (ppm)	Lead Q	Arsenic (ppm)	As Q
9650 Glacier Lane	0600-0-6"	0-6"	1	210		25	
9650 Glacier Lane	0601-6-12"	6-12"	1	98		21	
9650 Glacier Lane	0602-12-18"	12-18"	1	120		19	
9650 Glacier Lane	0603-0-6"	0-6"	2	590		140	
9650 Glacier Lane	0604-6-12"	6-12"	2	360		81	
9650 Glacier Lane	0605-12-18"	12-18"	2	64		17	
9650 Glacier Lane	0606-0-6"	0-6"	3	480		32	
9650 Glacier Lane	0607-6-12"	6-12"	3	530		39	
9650 Glacier Lane	0608-12-18"	12-18"	3	510		42	
9650 Glacier Lane	0611-0-6"	0-6"	4	270		19	
9650 Glacier Lane	0612-6-12"	6-12"	4	180		17	
9650 Glacier Lane	0613-12-18"	12-18"	4	41		11	
9650 Glacier Lane	0614-0-6"	0-6"	5	260		23	
9650 Glacier Lane	0615-6-12"	6-12"	5	190		23	
9650 Glacier Lane	0616-12-18"	12-18"	5	56		12	
9650 Glacier Lane	0623-0-6"	0-6"	6	250		25	
9650 Glacier Lane	0624-6-12"	6-12"	6	250		25	
9650 Glacier Lane	0626-12-18"	12-18"	6	230		25	
9650 Glacier Lane	0627-0-6"	0-6"	7	270		24	
9650 Glacier Lane	0628-6-12"	6-12"	7	260		27	
9650 Glacier Lane	0629-12-18"	12-18"	7	180		23	
9600 Glacier Lane	0630-0-6"	0-6"	1	180		21	
9600 Glacier Lane	0631-6-12"	6-12"	1	160		23	
9600 Glacier Lane	0632-12-18"	12-18"	1	120		20	
9600 Glacier Lane	0636-0-6"	0-6"	2	250		28	
9600 Glacier Lane	0637-6-12"	6-12"	2	200		25	
9600 Glacier Lane	0638-12-18"	12-18"	2	230		21	
9600 Glacier Lane	0643-0-6"	0-6"	3	120		17	
9600 Glacier Lane	0644-6-12"	6-12"	3	170		18	
9600 Glacier Lane	0645-12-18"	12-18"	3	88		12	
9600 Glacier Lane	0647-0-6"	0-6"	5	240		27	
9600 Glacier Lane	0648-6-12"	6-12"	5	270		29	
9600 Glacier Lane	0649-12-18"	12-18"	5	150		20	
9600 Glacier Lane	0650-0-6"	0-6"	4	210		22	
9600 Glacier Lane	0651-6-12"	6-12"	4	200		21	
9600 Glacier Lane	0652-12-18"	12-18"	4	230		24	
9600 Glacier Lane	0653-0-6"	0-6"	6	290		29	
9600 Glacier Lane	0654-6-12"	6-12"	6	200		20	
9600 Glacier Lane	0655-12-18"	12-18"	6	60		10	
9600 Glacier Lane	0656-0-6"	0-6"	7	220		20	
9600 Glacier Lane	0657-6-12"	6-12"	7	190		22	
9600 Glacier Lane	0658-12-18"	12-18"	7	250		24	
9600 Glacier Lane	0659-0-6"	0-6"	8	88		12	
9600 Glacier Lane	0660-6-12"	6-12"	8	170		24	
9600 Glacier Lane	0661-12-18"	12-18"	8	440		38	
9600 Glacier Lane	0662-0-6"	0-6"	9	110		20	
9600 Glacier Lane	0663-6-12"	6-12"	9	180		21	
9600 Glacier Lane	0664-12-18"	12-18"	9	200		21	
9600 Glacier Lane	0671-0-6"	0-6"	10	150		14	
9600 Glacier Lane	0672-6-12"	6-12"	10	270		25	
9600 Glacier Lane	0673-12-18"	12-18"	10	59		9.7	
9600 Glacier Lane	0674-0-6"	0-6"	11	780		49	
9600 Glacier Lane	0675-6-12"	6-12"	11	970		65	
9600 Glacier Lane	0676-12-18"	12-18"	11	470		36	
9600 Glacier Lane	0678-0-6"	0-6"	12	180		15	

Location	Sample Number	Depth	Zone	Lead (ppm)	Lead Q	Arsenic (ppm)	As Q
9600 Glacier Lane	0679-6-12"	6-12"	12	110		14	
9600 Glacier Lane	0680-12-18"	12-18"	12	77		11	
9520 Glacier Lane	0681-0-6"	0-6"	1	95		95	
9520 Glacier Lane	0682-6-12"	6-12"	1	97		97	
9520 Glacier Lane	0683-12-18"	12-18"	1	93		93	
9520 Glacier Lane	0684-0-6"	0-6"	2	320		320	
9520 Glacier Lane	0685-6-12"	6-12"	2	120		120	
9520 Glacier Lane	0686-12-18"	12-18"	2	60		60	
9520 Glacier Lane	0691-0-6"	0-6"	3	93		93	
9520 Glacier Lane	0692-6-12"	6-12"	3	130		130	
9520 Glacier Lane	0693-12-18"	12-18"	3	250		250	
9520 Glacier Lane	0694-0-6"	0-6"	4	340		340	
9520 Glacier Lane	0695-6-12"	6-12"	4	210		210	
9520 Glacier Lane	0696-12-18"	12-18"	4	300		300	
9516 Glacier Lane	0698-0-6"	0-6"	1	180		19	
9516 Glacier Lane	0699-6-12"	6-12"	1	400		37	
9516 Glacier Lane	0700-12-18"	12-18"	1	140		16	
9516 Glacier Lane	0701-0-6"	0-6"	2	210		16	
9516 Glacier Lane	0702-6-12"	6-12"	2	410		28	
9516 Glacier Lane	0703-12-18"	12-18"	2	250		19	
9516 Glacier Lane	0707-0-6"	0-6"	3	210		24	
9516 Glacier Lane	0708-6-12"	6-12"	3	75		14	
9516 Glacier Lane	0709-12-18"	12-18"	3	220		25	
9516 Glacier Lane	0710-0-6"	0-6"	4	110		17	
9516 Glacier Lane	0711-6-12"	6-12"	4	250		27	
9516 Glacier Lane	0712-12-18"	12-18"	4	100		16	
9612 Glacier Lane	0713-0-6"	0-6"	1	410		35	
9612 Glacier Lane	0714-6-12"	6-12"	1	240		25	
9612 Glacier Lane	0715-12-18"	12-18"	1	60		11	
9612 Glacier Lane	0717-0-6"	0-6"	2	220		21	
9612 Glacier Lane	0718-6-12"	6-12"	2	110		16	
9612 Glacier Lane	0719-12-18"	12-18"	2	99		13	
9612 Glacier Lane	0720-0-6"	0-6"	3	290		28	
9612 Glacier Lane	0721-6-12"	6-12"	3	280		28	
9612 Glacier Lane	0722-12-18"	12-18"	3	240		25	
9612 Glacier Lane	0723-0-6"	0-6"	4	290		24	
9612 Glacier Lane	0724-6-12"	6-12"	4	280		24	
9612 Glacier Lane	0725-12-18"	12-18"	4	390		28	
9612 Glacier Lane	0731-0-6"	0-6"	5	470		39	
9612 Glacier Lane	0732-6-12"	6-12"	5	300		32	
9612 Glacier Lane	0733-12-18"	12-18"	5	360		32	
3601 Little Cottonwood Canyon Road (Alta Academy)	0772-0-6"	0-6"	1	81		12	
3601 Little Cottonwood Canyon Road (Alta Academy)	0773-6-12"	6-12"	1	490		42	
3601 Little Cottonwood Canyon Road (Alta Academy)	0774-12-18"	12-18"	1	200		21	
3601 Little Cottonwood Canyon Road (Alta Academy)	0775-0-6"	0-6"	2	84		12	
3601 Little Cottonwood Canyon Road (Alta Academy)	0776-6-12"	6-12"	2	360		28	
3601 Little Cottonwood Canyon Road (Alta Academy)	0777-12-18"	12-18"	2	180		19	
3601 Little Cottonwood Canyon Road (Alta Academy)	0781-0-6"	0-6"	3	110		13	
3601 Little Cottonwood Canyon Road (Alta Academy)	0782-6-12"	6-12"	3	180		15	
3601 Little Cottonwood Canyon Road (Alta Academy)	0783-12-18"	12-18"	3	110		14	
3601 Little Cottonwood Canyon Road (Alta Academy)	0784-0-6"	0-6"	4	75		11	
3601 Little Cottonwood Canyon Road (Alta Academy)	0785-6-12"	6-12"	4	61		12	
3601 Little Cottonwood Canyon Road (Alta Academy)	0786-12-18"	12-18"	4	56		13	
3601 Little Cottonwood Canyon Road (Alta Academy)	0789-0-6"	0-6"	5	100		11	
3601 Little Cottonwood Canyon Road (Alta Academy)	0790-6-12"	6-12"	5	110		13	

Location	Sample Number	Depth	Zone	Lead (ppm)	Lead Q	Arsenic (ppm)	As Q
3601 Little Cottonwood Canyon Road (Alta Academy)	0791-12-18"	12-18"	5	55		11	
3601 Little Cottonwood Canyon Road (Alta Academy)	0792-0-6"	0-6"	6	97		11	
3601 Little Cottonwood Canyon Road (Alta Academy)	0793-6-12"	6-12"	6	220		18	
3601 Little Cottonwood Canyon Road (Alta Academy)	0794-12-18"	12-18"	6	97		12	
3601 Little Cottonwood Canyon Road (Alta Academy)	0796-0-6"	0-6"	7	140		11	
3601 Little Cottonwood Canyon Road (Alta Academy)	0797-6-12"	6-12"	7	650		36	
3601 Little Cottonwood Canyon Road (Alta Academy)	0798-12-18"	12-18"	7	310		25	
3601 Little Cottonwood Canyon Road (Alta Academy)	0801-0-6"	0-6"	8	150		16	
3601 Little Cottonwood Canyon Road (Alta Academy)	0802-6-12"	6-12"	8	71		16	
3601 Little Cottonwood Canyon Road (Alta Academy)	0803-12-18"	12-18"	8	70		14	
3601 Little Cottonwood Canyon Road (Alta Academy)	0806-0-6"	0-6"	9	460		21	
3601 Little Cottonwood Canyon Road (Alta Academy)	0807-6-12"	6-12"	9	440		24	
3601 Little Cottonwood Canyon Road (Alta Academy)	0808-12-18"	12-18"	9	450		25	
3601 Little Cottonwood Canyon Road (Alta Academy)	0809-0-6"	0-6"	10	310		15	
3601 Little Cottonwood Canyon Road (Alta Academy)	0810-6-12"	6-12"	10	380		23	
3601 Little Cottonwood Canyon Road (Alta Academy)	0811-12-18"	12-18"	10	1000		41	
3601 Little Cottonwood Canyon Road (Alta Academy)	0815-0-6"	0-6"	11	340		20	
3601 Little Cottonwood Canyon Road (Alta Academy)	0816-6-12"	6-12"	11	420		26	
3601 Little Cottonwood Canyon Road (Alta Academy)	0817-12-18"	12-18"	11	900		55	
3601 Little Cottonwood Canyon Road (Alta Academy)	0818-0-6"	0-6"	12	270		21	
3601 Little Cottonwood Canyon Road (Alta Academy)	0819-6-12"	6-12"	12	500		28	
3601 Little Cottonwood Canyon Road (Alta Academy)	0820-12-18"	12-18"	12	820		49	
3601 Little Cottonwood Canyon Road (Alta Academy)	0821-0-6"	0-6"	13	410		28	
3601 Little Cottonwood Canyon Road (Alta Academy)	0822-6-12"	6-12"	13	340		29	
3601 Little Cottonwood Canyon Road (Alta Academy)	0824-12-18"	12-18"	13	330		27	
3601 Little Cottonwood Canyon Road (Alta Academy)	0825-0-6"	0-6"	14	160		18	
3601 Little Cottonwood Canyon Road (Alta Academy)	0826-6-12"	6-12"	14	95		14	
3601 Little Cottonwood Canyon Road (Alta Academy)	0827-12-18"	12-18"	14	110		14	
3601 Little Cottonwood Canyon Road (Alta Academy)	0828-0-6"	0-6"	15	38		7.8	
3601 Little Cottonwood Canyon Road (Alta Academy)	0829-6-12"	6-12"	15	35		8.8	
3601 Little Cottonwood Canyon Road (Alta Academy)	0830-12-18"	12-18"	15	37		8.4	
3601 Little Cottonwood Canyon Road (Alta Academy)	0831-0-6"	0-6"	16	54		12	
3601 Little Cottonwood Canyon Road (Alta Academy)	0832-6-12"	6-12"	16	150		20	
3601 Little Cottonwood Canyon Road (Alta Academy)	0833-12-18"	12-18"	16	130		19	
3601 Little Cottonwood Canyon Road (Alta Academy)	0839-0-6"	0-6"	17	46		11	
3601 Little Cottonwood Canyon Road (Alta Academy)	0840-6-12"	6-12"	17	44		12	
3601 Little Cottonwood Canyon Road (Alta Academy)	0841-12-18"	12-18"	17	86		14	
3601 Little Cottonwood Canyon Road (Alta Academy)	0842-0-6"	0-6"	18	150		21	
3601 Little Cottonwood Canyon Road (Alta Academy)	0843-6-12"	6-12"	18	140		19	
3601 Little Cottonwood Canyon Road (Alta Academy)	0844-12-18"	12-18"	18	190		22	
3541 Little Cottonwood Canyon Rd.	0873-0-6"	0-6"	1	87		14	
3541 Little Cottonwood Canyon Rd.	0874-6-12"	6-12"	1	43		12	
3541 Little Cottonwood Canyon Rd.	0875-12-18"	12-18"	1	22		10	
3541 Little Cottonwood Canyon Rd.	0876-0-6"	0-6"	2	46		8	
3541 Little Cottonwood Canyon Rd.	0877-6-12"	6-12"	2	71		11	
3541 Little Cottonwood Canyon Rd.	0878-12-18"	12-18"	2	59		9	
3541 Little Cottonwood Canyon Rd.	0881-0-6"	0-6"	3	85		7	
3541 Little Cottonwood Canyon Rd.	0882-6-12"	6-12"	3	80		7	
3541 Little Cottonwood Canyon Rd.	0883-12-18"	12-18"	3	110		9	
3541 Little Cottonwood Canyon Rd.	0886-0-6"	0-6"	play	21		5	U
3541 Little Cottonwood Canyon Rd.	0887-6-12"	6-12"	play	73		7	
3541 Little Cottonwood Canyon Rd.	0888-12-18"	12-18"	play	110		17	
3541 Little Cottonwood Canyon Rd.	0890-0-6"	0-6"	4	110		9	
3541 Little Cottonwood Canyon Rd.	0891-6-12"	6-12"	4	53		6	
3541 Little Cottonwood Canyon Rd.	0892-12-18"	12-18"	4	89		13	

Location	Sample Number	Depth	Zone	Lead (ppm)	Lead Q	Arsenic (ppm)	As Q
le Cottonwood Canyon Rd. S. E. Vacant Lot (South of Pa	0867-0-6"	0-6"	1	220		28	
le Cottonwood Canyon Rd. S. E. Vacant Lot (South of Pa	08686-12"	6-12"	1	350		24	
le Cottonwood Canyon Rd. S. E. Vacant Lot (South of Pa	0869-12-18"	12-18"	1	310		37	
le Cottonwood Canyon Rd. S. E. Vacant Lot (South of Pa	0870-0-6"	0-6"	2	370		23	
le Cottonwood Canyon Rd. S. E. Vacant Lot (South of Pa	0871-6-12"	6-12"	2	220		28	
le Cottonwood Canyon Rd. S. E. Vacant Lot (South of Pa	0872-12-18"	12-18"	2	290		5	U
9767 Little Cottonwood Place	0751-0-6"	0-6"	1	270		20	
9767 Little Cottonwood Place	0752-6-12"	6-12"	1	260		21	
9767 Little Cottonwood Place	0753-12-18"	12-18"	1	310		20	
9767 Little Cottonwood Place	0755-0-6"	0-6"	2	130		14	
9767 Little Cottonwood Place	0756-6-12"	6-12"	2	480		27	
9767 Little Cottonwood Place	0757-12-18"	12-18"	2	55		7	
9767 Little Cottonwood Place	0758-0-6"	0-6"	3	1100		100	
9767 Little Cottonwood Place	0759-6-12"	6-12"	3	3200		110	
9767 Little Cottonwood Place	0760-12-18"	12-18"	3	540		60	
9767 Little Cottonwood Place	0761-0-6"	0-6"	4	510		28	
9767 Little Cottonwood Place	0762-6-12"	6-12"	4	110		15	
9767 Little Cottonwood Place	0763-12-18"	12-18"	4	410		31	
9767 Little Cottonwood Place	0769-0-6"	0-6"	5	300		22	
9767 Little Cottonwood Place	0770-6-12"	6-12"	5	340		18	
9767 Little Cottonwood Place	0771-12-18"	12-18"	5	35		5	
9751 Little Cottonwood Place	0024-0-6"	0-6"	1	21		9	
9751 Little Cottonwood Place	0025-6-12"	6-12"	1	50		16	
9751 Little Cottonwood Place	0026-12-18"	12-18"	1	98		17	
9751 Little Cottonwood Place	0027-12-18"	12-18"	2	29		14	
9751 Little Cottonwood Place	0028-0-6"	0-6"	2	36		15	
9751 Little Cottonwood Place	0029-6-12"	6-12"	2	29		9	
9751 Little Cottonwood Place	0030-0-6"	0-6"	3	400		34	
9751 Little Cottonwood Place	0031-6-12"	6-12"	3	420		28	
9751 Little Cottonwood Place	0032-12-18"	12-18"	3	61		7	
9751 Little Cottonwood Place	0033-0-6"	0-6"	4	720		71	
9751 Little Cottonwood Place	0034-6-12"	6-12"	4	630		51	
9751 Little Cottonwood Place	0035-12-18"	12-18"	4	110		11	
9764 Little Cottonwood Place	0041-0-6"	0-6"	1	100		13	
9764 Little Cottonwood Place	0042-6-12"	6-12"	1	110		11	
9764 Little Cottonwood Place	0043-12-18"	12-18"	1	100		10	
9764 Little Cottonwood Place	0044-0-6"	0-6"	2	59		6	
9764 Little Cottonwood Place	0045-6-12"	6-12"	2	58		6	
9764 Little Cottonwood Place	0046-0-6"	0-6"	4	560		32	
9764 Little Cottonwood Place	0047-12-18"	12-18"	2	370		27	
9764 Little Cottonwood Place	0048-0-6"	0-6"	3	25		9	
9764 Little Cottonwood Place	0049-6-12"	6-12"	3	610		44	
9764 Little Cottonwood Place	0050-12-18"	12-18"	3	790		62	
9764 Little Cottonwood Place	0051-6-12"	6-12"	4	110		18	
9764 Little Cottonwood Place	0052-12-18"	12-18"	4	91		18	
9752 Little Cottonwood Place	0057-0-6"	0-6"	1	34		9	
9752 Little Cottonwood Place	0058-6-12"	6-12"	1	100		13	
9752 Little Cottonwood Place	0059-12-18"	12-18"	1	120		9	
9752 Little Cottonwood Place	0060-0-6"	0-6"	2	35		12	
9752 Little Cottonwood Place	0061-6-12"	6-12"	2	53		12	
9752 Little Cottonwood Place	0062-12-18"	12-18"	2	47		8	
9752 Little Cottonwood Place	0063-0-6"	0-6"	3	28		8	
9752 Little Cottonwood Place	0064-6-12"	6-12"	3	31		5	
9752 Little Cottonwood Place	0065-12-18"	12-18"	3	160		16	
9752 Little Cottonwood Place	0067-0-6"	0-6"	4	39		7	

Location	Sample Number	Depth	Zone	Lead (ppm)	Lead Q	Arsenic (ppm)	As Q
9752 Little Cottonwood Place	0068-6-12"	6-12"	4	140		17	
9752 Little Cottonwood Place	0069-12-18"	12-18"	4	71		11	
Grow Park, Mountain Valley Way	0848-0-6"	0-6"	1	71		13	
Grow Park, Mountain Valley Way	0849-6-12"	6-12"	1	150		18	
Grow Park, Mountain Valley Way	0850-12-18"	12-18"	1	100		12	
Grow Park, Mountain Valley Way	0854-0-6"	0-6"	2	75		10	
Grow Park, Mountain Valley Way	0855-6-12"	6-12"	2	160		14	
Grow Park, Mountain Valley Way	0856-12-18"	12-18"	2	93		10	
Grow Park, Mountain Valley Way	0859-0-6"	0-6"	3	55		11	
Grow Park, Mountain Valley Way	0860-6-12"	6-12"	3	73		17	
Grow Park, Mountain Valley Way	0861-12-18"	12-18"	3	34		9	
Grow Park, Mountain Valley Way	0862-0-6"	0-6"	4	78		17	
Grow Park, Mountain Valley Way	0863-6-12"	6-12"	4	72		15	
Grow Park, Mountain Valley Way	0864-12-18"	12-18"	4	46		12	
3660 N. Little Cottonwood Road	0410-0-6"	0-6"	1	710		25	
3660 N. Little Cottonwood Road	0411-6-12"	6-12"	1	330		15	
3660 N. Little Cottonwood Road	0412-12-18"	12-18"	1	880		35	
3660 N. Little Cottonwood Road	0413-0-6"	0-6"	2	410		19	
3660 N. Little Cottonwood Road	0414-6-12"	6-12"	2	560		29	
3660 N. Little Cottonwood Road	0415-12-18"	12-18"	2	710		29	
3660 N. Little Cottonwood Road	0416-0-6"	0-6"	3	86		15	
3660 N. Little Cottonwood Road	0417-6-12"	6-12"	3	630		33	
3660 N. Little Cottonwood Road	0418-12-18"	12-18"	3	530		28	
3660 N. Little Cottonwood Road	0420-0-6"	0-6"	4	3900		150	
3660 N. Little Cottonwood Road	0421-6-12"	6-12"	4	1600		88	
3660 N. Little Cottonwood Road	0422-12-18"	12-18"	4	2100		97	
3660 N. Little Cottonwood Road	0423-0-6"	0-6"	5	1400		50	
3660 N. Little Cottonwood Road	0424-6-12"	6-12"	5	260		20	
3660 N. Little Cottonwood Road	0425-12-18"	12-18"	5	53		10	
3660 N. Little Cottonwood Road	0426-0-6"	0-6"	6	10000		540	
3660 N. Little Cottonwood Road	0427-6-12"	6-12"	6	1900		100	
3660 N. Little Cottonwood Road	0428-12-18"	12-18"	6	1600		84	
3660 N. Little Cottonwood Road	0429-0-6"	0-6"	7	6300		300	
3660 N. Little Cottonwood Road	0430-6-12"	6-12"	7	8300		310	
3660 N. Little Cottonwood Road	0431-12-18"	12-18"	7	3500		140	
3660 N. Little Cottonwood Road	0432-0-6"	0-6"	8	2000		71	
3660 N. Little Cottonwood Road	0433-6-12"	6-12"	8	8500		270	
3660 N. Little Cottonwood Road	0434-12-18"	12-18"	8	3500		110	
3660 N. Little Cottonwood Road	0446-0-6"	0-6"	9	31		8	
3660 N. Little Cottonwood Road	0447-6-12"	6-12"	9	16		8	
3660 N. Little Cottonwood Road	0448-12-18"	12-18"	9	21		8	
3660 N. Little Cottonwood Road	0455-0-6"	0-6"	10	420		23	
3660 N. Little Cottonwood Road	0456-6-12"	6-12"	10	410		23	
3660 N. Little Cottonwood Road	0457-12-18"	12-18"	10	830		40	
3660 N. Little Cottonwood Road	0459-0-6"	0-6"	11	140		11	
3660 N. Little Cottonwood Road	0460-6-12"	6-12"	11	80		9	
3660 N. Little Cottonwood Road	0461-12-18"	12-18"	11	120		11	
3660 N. Little Cottonwood Road	0463-0-6"	0-6"	12	2000		85	
3660 N. Little Cottonwood Road	0464-6-12"	6-12"	12	2200		90	
3660 N. Little Cottonwood Road	0465-12-18"	12-18"	12	2300		87	
3660 N. Little Cottonwood Road	0466-0-6"	0-6"	13	960		65	
3660 N. Little Cottonwood Road	0467-6-12"	6-12"	13	140		24	
3660 N. Little Cottonwood Road	0468-12-18"	12-18"	13	91		15	
3660 N. Little Cottonwood Road	0469-0-6"	0-6"	14	1700		62	
3660 N. Little Cottonwood Road	0470-6-12"	6-12"	14	1300		59	

Location	Sample Number	Depth	Zone	Lead (ppm)	Lead Q	Arsenic (ppm)	As Q
3660 N. Little Cottonwood Road	0471-12-18"	12-18"	14	1900		69	
3660 N. Little Cottonwood Road	0472-0-6"	0-6"	15	660		34	
3660 N. Little Cottonwood Road	0473-6-12"	6-12"	15	580		31	
3660 N. Little Cottonwood Road	0474-12-18"	12-18"	15	160		19	
3660 N. Little Cottonwood Road	0475-0-6"	0-6"	garden	44		11	
3660 N. Little Cottonwood Road	0476-6-12"	6-12"	garden	1300		60	
3660 N. Little Cottonwood Road	0477-12-18"	12-18"	garden	1300		67	
3742 N. Little Cottonwood Road	0478-0-6"	0-6"	1	240		24	
3742 N. Little Cottonwood Road	0479-6-12"	6-12"	1	120		19	
3742 N. Little Cottonwood Road	0480-12-18"	12-18"	1	25		6	
3742 N. Little Cottonwood Road	0481-0-6"	0-6"	2	160		16	
3742 N. Little Cottonwood Road	0482-6-12"	6-12"	2	160		19	
3742 N. Little Cottonwood Road	0483-12-18"	12-18"	2	41		10	
3742 N. Little Cottonwood Road	0484-0-6"	0-6"	3	320		23	
3742 N. Little Cottonwood Road	0485-6-12"	6-12"	3	140		17	
3742 N. Little Cottonwood Road	0486-12-18"	12-18"	3	32		9	
3742 N. Little Cottonwood Road	0492-0-6"	0-6"	4	240		18	
3742 N. Little Cottonwood Road	0493-6-12"	6-12"	4	65		12	
3742 N. Little Cottonwood Road	0494-12-18"	12-18"	4	25		11	
3742 N. Little Cottonwood Road	0495-12-18"	12-18"	5	260		20	
3742 N. Little Cottonwood Road	0496-6-12"	6-12"	5	340		25	
3742 N. Little Cottonwood Road	0497-0-6"	0-6"	5	240		23	
3710 N. Little Cottonwood Road	0498-0-6"	0-6"	1	140		19	
3710 N. Little Cottonwood Road	0499-6-12"	6-12"	1	120		15	
3710 N. Little Cottonwood Road	0500-12-18"	12-18"	1	140		16	
3710 N. Little Cottonwood Road	0501-0-6"	0-6"	2	970		82	
3710 N. Little Cottonwood Road	0502-6-12"	6-12"	2	200		24	
3710 N. Little Cottonwood Road	0503-12-18"	12-18"	2	49		16	
3710 N. Little Cottonwood Road	0505-0-6"	0-6"	3	860		51	
3710 N. Little Cottonwood Road	0506-6-12"	6-12"	3	760		51	
3710 N. Little Cottonwood Road	0507-12-18"	12-18"	3	770		48	
3710 N. Little Cottonwood Road	0508-0-6"	0-6"	4	500		30	
3710 N. Little Cottonwood Road	0509-6-12"	6-12"	4	380		26	
3710 N. Little Cottonwood Road	0510-12-18"	12-18"	4	57		13	
3710 N. Little Cottonwood Road	0511-0-6"	0-6"	5	650		43	
3710 N. Little Cottonwood Road	0512-6-12"	6-12"	5	660		45	
3710 N. Little Cottonwood Road	0513-12-18"	12-18"	5	620		43	
3710 N. Little Cottonwood Road	0514-0-6"	0-6"	6	1300		70	
3710 N. Little Cottonwood Road	0515-6-12"	6-12"	6	1300		76	
3710 N. Little Cottonwood Road	0516-12-18"	12-18"	6	240		34	
3710 N. Little Cottonwood Road	0517-0-6"	0-6"	7	490		42	
3710 N. Little Cottonwood Road	0518-6-12"	6-12"	7	420		41	
3710 N. Little Cottonwood Road	0519-12-18"	12-18"	7	96		13	
3710 N. Little Cottonwood Road	0520-0-6"	0-6"	8	740		47	
3710 N. Little Cottonwood Road	0521-6-12"	6-12"	8	620		44	
3710 N. Little Cottonwood Road	0522-12-18"	12-18"	8	33		6	
3710 N. Little Cottonwood Road	0525-0-6"	0-6"	9	650		45	
3710 N. Little Cottonwood Road	0526-6-12"	6-12"	9	790		62	
3710 N. Little Cottonwood Road	0527-12-18"	12-18"	9	710		60	
3710 N. Little Cottonwood Road	0528-0-6"	0-6"	10	980		61	
3710 N. Little Cottonwood Road	0529-6-12"	6-12"	10	350		22	
3710 N. Little Cottonwood Road	0530-12-18"	12-18"	10	410		24	
3710 N. Little Cottonwood Road	0533-0-6"	0-6"	11	980		68	
3710 N. Little Cottonwood Road	0534-6-12"	6-12"	11	320		23	
3710 N. Little Cottonwood Road	0535-12-18"	12-18"	11	1100		67	

Location	Sample Number	Depth	Zone	Lead (ppm)	Lead Q	Arsenic (ppm)	As Q
3656 N. Little Cottonwood Road	0546-0-6"	0-6"	1	61		8	
3656 N. Little Cottonwood Road	0547-6-12"	6-12"	1	270		15	
3656 N. Little Cottonwood Road	0548-12-18"	12-18"	1	190		15	
3656 N. Little Cottonwood Road	0549-0-6"	0-6"	2	1000		45	
3656 N. Little Cottonwood Road	0550-6-12"	6-12"	2	1000		42	
3656 N. Little Cottonwood Road	0551-12-18"	12-18"	2	820		39	
3656 N. Little Cottonwood Road	0555-0-6"	0-6"	3	690		47	
3656 N. Little Cottonwood Road	0556-6-12"	6-12"	3	810		50	
3656 N. Little Cottonwood Road	0560-12-18"	12-18"	3	1100		54	
3656 N. Little Cottonwood Road	0561-0-6"	0-6"	4	99		25	
3656 N. Little Cottonwood Road	0562-6-12"	6-12"	4	240		26	
3656 N. Little Cottonwood Road	0563-12-18"	12-18"	4	110		23	
3656 N. Little Cottonwood Road	0565-0-6"	0-6"	5	6800		210	
3656 N. Little Cottonwood Road	0567-6-12"	6-12"	5	4000		130	
3656 N. Little Cottonwood Road	0568-12-18"	12-18"	5	98		10	
3656 N. Little Cottonwood Road	0569-0-6"	0-6"	6	13000		630	
3656 N. Little Cottonwood Road	0570-6-12"	6-12"	6	1500		61	
3656 N. Little Cottonwood Road	0571-12-18"	12-18"	6	12000		500	
3656 N. Little Cottonwood Road	0572-0-6"	0-6"	7	820		36	
3656 N. Little Cottonwood Road	0573-6-12"	6-12"	7	660		24	
3656 N. Little Cottonwood Road	0574-12-18"	12-18"	7	770		28	
chmidt Barn due west of 3744 N. Little Cottonwood Roa	0575-0-6"	0-6"	1	600		35	
chmidt Barn due west of 3744 N. Little Cottonwood Roa	0576-6-12"	6-12"	1	510		50	
chmidt Barn due west of 3744 N. Little Cottonwood Roa	0577-12-18"	12-18"	1	630		40	
chmidt Barn due west of 3744 N. Little Cottonwood Roa	0578-0-6"	0-6"	2	28		10	
chmidt Barn due west of 3744 N. Little Cottonwood Roa	0579-6-12"	6-12"	2	250		17	
chmidt Barn due west of 3744 N. Little Cottonwood Roa	0580-12-18"	12-18"	2	570		27	
chmidt Barn due west of 3744 N. Little Cottonwood Roa	0581-0-6"	0-6"	3	540		27	
chmidt Barn due west of 3744 N. Little Cottonwood Roa	0582-6-12"	6-12"	3	620		36	
chmidt Barn due west of 3744 N. Little Cottonwood Roa	0583-12-18"	12-18"	3	180		20	
3744 N. Little Cottonwood Road	0588-0-6"	0-6"	1	27		7	
3744 N. Little Cottonwood Road	0589-6-12"	6-12"	1	35		10	
3744 N. Little Cottonwood Road	0590-12-18"	12-18"	1	160		17	
3744 N. Little Cottonwood Road	0591-0-6"	0-6"	2	330		21	
3744 N. Little Cottonwood Road	0592-6-12"	6-12"	2	87		10	
3744 N. Little Cottonwood Road	0593-12-18"	12-18"	2	180		17	
3744 N. Little Cottonwood Road	0594-0-6"	0-6"	3	79		9	
3744 N. Little Cottonwood Road	0595-6-12"	6-12"	3	81		12	
3744 N. Little Cottonwood Road	0596-12-18"	12-18"	3	110		13	
3744 N. Little Cottonwood Road	0597-0-6"	0-6"	4	250		22	
3744 N. Little Cottonwood Road	0598-6-12"	6-12"	4	78		12	
3744 N. Little Cottonwood Road	0599-12-18"	12-18"	4	38		5	U
9756 Old Ranch Place	0137-0-6"	0-6"	1	28		9	
9756 Old Ranch Place	0138-6-12"	6-12"	1	100		15	
9756 Old Ranch Place	0139-12-18"	12-18"	1	260		31	
9756 Old Ranch Place	0140-0-6"	0-6"	2	19000		480	
9756 Old Ranch Place	0141-6-12"	6-12"	2	9500		360	
9756 Old Ranch Place	0142-12-18"	12-18"	2	2100		150	
9756 Old Ranch Place	0146-0-6"	0-6"	3	8300		2000	
9756 Old Ranch Place	0147-6-12"	6-12"	3	500		150	
9756 Old Ranch Place	0148-12-18"	12-18"	3	3600		750	
9756 Old Ranch Place	0149-0-6"	0-6"	4	1300		77	
9756 Old Ranch Place	0150-6-12"	6-12"	4	260		54	
9756 Old Ranch Place	0151-12-18"	12-18"	4	30		14	
9756 Old Ranch Place	0154-0-6"	0-6"	5	970		23	

Location	Sample Number	Depth	Zone	Lead (ppm)	Lead Q	Arsenic (ppm)	As Q
9756 Old Ranch Place	0155-6-12"	6-12"	5	1500		27	
9756 Old Ranch Place	0156-12-18"	12-18"	5	2600		69	
9759 Old Ranch Place	0316-0-6"	0-6"	4	530		28	
9759 Old Ranch Place	0317-6-12"	6-12"	4	310		23	
9759 Old Ranch Place	0318-12-18"	12-18"	4	240		22	
9759 Old Ranch Place	0319-0-6"	0-6"	5	46		15	
9759 Old Ranch Place	0320-6-12"	6-12"	5	180		20	
9759 Old Ranch Place	0321-12-18"	12-18"	5	310		28	
9759 Old Ranch Place	0323-0-6"	0-6"	1	32		8	
9759 Old Ranch Place	0325-6-12"	6-12"	1	38		8	
9759 Old Ranch Place	0326-12-18"	12-18"	1	57		9	
9759 Old Ranch Place	0327-0-6"	0-6"	2	110		12	
9759 Old Ranch Place	0328-6-12"	6-12"	2	420		30	
9759 Old Ranch Place	0329-12-18"	12-18"	2	360		23	
9759 Old Ranch Place	0330-0-6"	0-6"	3	440		34	
9759 Old Ranch Place	0331-6-12"	6-12"	3	310		22	
9759 Old Ranch Place	0332-12-18"	12-18"	3	840		41	
9751 Old Ranch Place	0339-0-6"	0-6"	1	53		9	
9751 Old Ranch Place	0340-6-12"	6-12"	1	130		15	
9751 Old Ranch Place	0341-12-18"	12-18"	1	190		19	
9751 Old Ranch Place	0342-0-6"	0-6"	2	34		7	
9751 Old Ranch Place	0343-6-12"	6-12"	2	62		12	
9751 Old Ranch Place	0344-12-18"	12-18"	2	230		23	
9751 Old Ranch Place	0346-0-6"	0-6"	3	150		20	
9751 Old Ranch Place	0347-6-12"	6-12"	3	150		21	
9751 Old Ranch Place	0348-12-18"	12-18"	3	96		15	
9751 Old Ranch Place	0349-0-6"	0-6"	4	100		15	
9751 Old Ranch Place	0350-6-12"	6-12"	4	130		15	
9751 Old Ranch Place	0351-12-18"	12-18"	4	170		22	
9687 Quail Ridge Road	0182-0-6"	0-6"	1	150		10	
9687 Quail Ridge Road	0183-6-12"	6-12"	1	180		9	
9687 Quail Ridge Road	0184-12-18"	12-18"	1	370		20	
9687 Quail Ridge Road	0185-0-6"	0-6"	2	26		8	
9687 Quail Ridge Road	0186-6-12"	6-12"	2	230		16	
9687 Quail Ridge Road	0187-12-18"	12-18"	2	95		12	
9687 Quail Ridge Road	0188-0-6"	0-6"	3	520		23	
9687 Quail Ridge Road	0189-6-12"	6-12"	3	990		38	
9687 Quail Ridge Road	0190-12-18"	12-18"	3	590		30	
9687 Quail Ridge Road	0191-0-6"	0-6"	4	800		28	
9687 Quail Ridge Road	0192-6-12"	6-12"	4	420		21	
9687 Quail Ridge Road	0193-12-18"	12-18"	4	300		18	
9687 Quail Ridge Road	0197-0-6"	0-6"	5	930		44	
9687 Quail Ridge Road	0198-6-12"	6-12"	5	280		18	
9687 Quail Ridge Road	0199-12-18"	12-18"	5	130		15	
9682 Quail Ridge Road	0203-0-6"	0-6"	1	33		11	
9682 Quail Ridge Road	0204-6-12"	6-12"	1	270		18	
9682 Quail Ridge Road	0205-12-18"	12-18"	1	190		16	
9682 Quail Ridge Road	0206-0-6"	0-6"	2	100		12	
9682 Quail Ridge Road	0207-6-12"	6-12"	2	84		12	
9682 Quail Ridge Road	0208-12-18"	12-18"	2	210		19	
9682 Quail Ridge Road	0210-0-6"	0-6"	3	630		35	
9682 Quail Ridge Road	0211-6-12"	6-12"	3	110		9	
9682 Quail Ridge Road	0212-12-18"	12-18"	3	48		5	U
9682 Quail Ridge Road	0219-0-6"	0-6"	4	470		33	
9682 Quail Ridge Road	0220-6-12"	6-12"	4	740		46	

Location	Sample Number	Depth	Zone	Lead (ppm)	Lead Q	Arsenic (ppm)	As Q
9682 Quail Ridge Road	0221-12-18"	12-18"	4	150		20	
9682 Quail Ridge Road	0222-0-6"	0-6"	6	950		43	
9682 Quail Ridge Road	0223-6-12"	6-12"	6	1100		43	
9682 Quail Ridge Road	0224-12-18"	12-18"	6	420		29	
9682 Quail Ridge Road	0225-0-6"	0-6"	5	1300		29	
9682 Quail Ridge Road	0226-6-12"	6-12"	5	1300		80	
9682 Quail Ridge Road	0227-12-18"	12-18"	5	380		22	
9712 Quail Ridge Road	0228-0-6"	0-6"	1	170		12	
9712 Quail Ridge Road	0229-6-12"	6-12"	1	230		14	
9712 Quail Ridge Road	0230-12-18"	12-18"	1	380		21	
9712 Quail Ridge Road	0235-0-6"	0-6"	2	650		27	
9712 Quail Ridge Road	0236-6-12"	6-12"	2	950		45	
9712 Quail Ridge Road	0237-12-16"	12-16"	2	1200		57	
9712 Quail Ridge Road	0238-0-6"	0-6"	3	160		6	
9712 Quail Ridge Road	0239-6-12"	6-12"	3	41		5	U
9712 Quail Ridge Road	0240-12-18"	12-18"	3	180		10	
9712 Quail Ridge Road	0242-0-6"	0-6"	4	1500		72	
9712 Quail Ridge Road	0243-6-12"	6-12"	4	2300		100	
9712 Quail Ridge Road	0244-12-18"	12-18"	4	2000		79	
9715 Quail Ridge Road	0250-0-6"	0-6"	1	15		10	
9715 Quail Ridge Road	0251-6-12"	6-12"	1	73		13	
9715 Quail Ridge Road	0252-12-18"	12-18"	1	420		32	
9715 Quail Ridge Road	0253-12-18"	12-18"	2	880		34	
9715 Quail Ridge Road	0254-0-6"	0-6"	2	110		12	
9715 Quail Ridge Road	0255-6-12"	6-12"	2	410		19	
9715 Quail Ridge Road	0256-0-6"	0-6"	3	18		10	
9715 Quail Ridge Road	0257-6-12"	6-12"	3	1900		48	
9715 Quail Ridge Road	0258-12-18"	12-18"	3	1500		51	
9715 Quail Ridge Road	0259-0-6"	0-6"	4	41		12	
9715 Quail Ridge Road	0260-6-12"	6-12"	4	320		19	
9715 Quail Ridge Road	0261-12-18"	12-18"	4	300		18	
9715 Quail Ridge Road	0262-0-6"	0-6"	5	51		5	U
9715 Quail Ridge Road	0263-6-12"	6-12"	5	330		17	
9715 Quail Ridge Road	0264-12-18"	12-18"	5	1100		38	
9756 Quail Ridge Road	0270-0-6"	0-6"	1	45		11	
9756 Quail Ridge Road	0271-6-12"	6-12"	1	100		11	
9756 Quail Ridge Road	0272-12-18"	12-18"	1	70		6	
9756 Quail Ridge Road	0273-0-6"	0-6"	2	15		13	
9756 Quail Ridge Road	0274-6-12"	6-12"	2	170		13	
9756 Quail Ridge Road	0275-12-18"	12-18"	2	110		12	
9756 Quail Ridge Road	0276-0-6"	0-6"	3	1200		33	
9756 Quail Ridge Road	0277-6-12"	6-12"	3	2400		37	
9756 Quail Ridge Road	0278-12-18"	12-18"	3	1300		34	
9756 Quail Ridge Road	0279-0-6"	0-6"	4	150		16	
9756 Quail Ridge Road	0280-6-12"	6-12"	4	240		18	
9756 Quail Ridge Road	0281-12-18"	12-18"	4	630		22	
9753 Quail Ridge Road	0286-0-6"	0-6"	1	97		16	
9753 Quail Ridge Road	0287-6-12"	6-12"	1	1500		44	
9753 Quail Ridge Road	0288-12-18"	12-18"	1	3100		160	
9753 Quail Ridge Road	0289-0-6"	0-6"	3	470		43	
9753 Quail Ridge Road	0290-6-12"	6-12"	3	810		42	
9753 Quail Ridge Road	0291-12-18"	12-18"	3	190		23	
9753 Quail Ridge Road	0292-0-6"	0-6"	4	92		14	
9753 Quail Ridge Road	0294-6-12"	6-12"	4	72		14	
9753 Quail Ridge Road	0295-12-18"	12-18"	4	46		15	

Location	Sample Number	Depth	Zone	Lead (ppm)	Lead Q	Arsenic (ppm)	As Q
9753 Quail Ridge Road	0296-0-6"	0-6"	2	31		11	
9753 Quail Ridge Road	0297-6-12"	6-12"	2	24		15	
9753 Quail Ridge Road	0298-12-18"	12-18"	2	160		24	
9696 Quail Ridge Road	0299-0-6"	0-6"	1	130		17	
9696 Quail Ridge Road	0300-6-12"	6-12"	1	260		22	
9696 Quail Ridge Road	0301-12-18"	12-18"	1	320		14	
9696 Quail Ridge Road	0306-0-6"	0-6"	2	340		22	
9696 Quail Ridge Road	0307-6-12"	6-12"	2	340		21	
9696 Quail Ridge Road	0309-12-18"	12-18"	2	410		25	
9696 Quail Ridge Road	0310-0-6"	0-6"	3	1300		73	
9696 Quail Ridge Road	0311-6-12"	6-12"	3	180		28	
9696 Quail Ridge Road	0312-12-18"	12-18"	3	420		37	
9696 Quail Ridge Road	0313-0-6"	0-6"	4	1900		91	
9696 Quail Ridge Road	0314-6-12"	6-12"	4	2400		130	
9696 Quail Ridge Road	0315-12-18"	12-18"	4	550		51	
9726 Quail Ridge Road	0734-0-6"	0-6"	1	48		12	
9726 Quail Ridge Road	0735-6-12"	6-12"	1	80		13	
9726 Quail Ridge Road	0736-12-18"	12-18"	1	57		11	
9726 Quail Ridge Road	0737-0-6"	0-6"	2	110		13	
9726 Quail Ridge Road	0738-6-12"	6-12"	2	130		16	
9726 Quail Ridge Road	0739-12-18"	12-18"	2	95		13	
9726 Quail Ridge Road	0745-0-6"	0-6"	3	370		17	
9726 Quail Ridge Road	0746-6-12"	6-12"	3	520		22	
9726 Quail Ridge Road	0747-12-18"	12-18"	3	450		21	
9726 Quail Ridge Road	0748-0-6"	0-6"	4	2300		71	
9726 Quail Ridge Road	0749-6-12"	6-12"	4	2500		130	
9726 Quail Ridge Road	0750-12-18"	12-18"	4	2500		95	
3698 Little Cottonwood Lane	0006-0-6"	0-6"	1	22		8.4	
3698 Little Cottonwood Lane	0007-6-12"	6-12"	1	150		10	
3698 Little Cottonwood Lane	0008-12-18"	12-18"	1	390		18	
3698 Little Cottonwood Lane	0009-0-6"	0-6"	2	13		6.1	
3698 Little Cottonwood Lane	0010-6-12"	6-12"	2	14		12	
3698 Little Cottonwood Lane	0011-12-18"	12-18"	2	17		9.4	
3698 Little Cottonwood Lane	0012-0-6"	0-6"	3	33		8.8	
3698 Little Cottonwood Lane	0013-6-12"	6-12"	3	130		21	
3698 Little Cottonwood Lane	0014-12-18"	12-18"	3	480		37	
3698 Little Cottonwood Lane	0015-0-6"	0-6"	4	28		11	
3698 Little Cottonwood Lane	0016-6-12"	6-12"	4	58		9.3	
3698 Little Cottonwood Lane	0017-12-18"	12-18"	4	86		9.2	
3695 Little Cottonwood Lane	0074-0-6"	0-6"	1	77		16	
3695 Little Cottonwood Lane	0075-6-12"	6-12"	1	190		20	
3695 Little Cottonwood Lane	0076-12-18"	12-18"	1	360		32	
3695 Little Cottonwood Lane	0077-0-6"	0-6"	2	66		10	
3695 Little Cottonwood Lane	0078-6-12"	6-12"	2	170		22	
3695 Little Cottonwood Lane	0079-12-18"	12-18"	2	220		20	
3695 Little Cottonwood Lane	0080-0-6"	0-6"	3	250		19	
3695 Little Cottonwood Lane	0081-6-12"	6-12"	3	220		16	
3695 Little Cottonwood Lane	0082-12-18"	12-18"	3	120		13	
3695 Little Cottonwood Lane	0083-0-6"	0-6"	4	170		18	
3695 Little Cottonwood Lane	0084-6-12"	6-12"	4	350		27	
3695 Little Cottonwood Lane	0085-12-18"	12-18"	4	280		20	
3641 Little Cottonwood Lane	0090-0-6"	0-6"	1	75		23	
3641 Little Cottonwood Lane	0091-6-12"	6-12"	1	100		17	
3641 Little Cottonwood Lane	0092-12-18"	12-18"	1	300		16	
3641 Little Cottonwood Lane	0093-0-6"	0-6"	2	160		23	

Location	Sample Number	Depth	Zone	Lead (ppm)	Lead Q	Arsenic (ppm)	As Q
3641 Little Cottonwood Lane	0094-6-12"	6-12"	2	41		15	
3641 Little Cottonwood Lane	0095-12-18"	12-18"	2	62		15	
3641 Little Cottonwood Lane	0096-0-6"	0-6"	3	28		9	
3641 Little Cottonwood Lane	0097-6-12"	6-12"	3	22		7	
3641 Little Cottonwood Lane	0098-12-18"	12-18"	3	320		27	
3641 Little Cottonwood Lane	0100-0-6"	0-6"	4	23		12	
3641 Little Cottonwood Lane	0101-6-12"	6-12"	4	120		18	
3641 Little Cottonwood Lane	0102-12-18"	12-18"	4	250		21	
3652 Little Cottonwood Lane	0105-0-6"	0-6"	1	47		9	
3652 Little Cottonwood Lane	0106-6-12"	6-12"	1	260		22	
3652 Little Cottonwood Lane	0107-12-18"	12-18"	1	470		33	
3652 Little Cottonwood Lane	0108-0-6"	0-6"	2	86		14	
3652 Little Cottonwood Lane	0109-6-12"	6-12"	2	230		23	
3652 Little Cottonwood Lane	0110-12-18"	12-18"	2	190		17	
3652 Little Cottonwood Lane	0114-0-6"	0-6"	3	37		12	
3652 Little Cottonwood Lane	0115-6-12"	6-12"	3	72		13	
3652 Little Cottonwood Lane	0116-12-18"	12-18"	3	81		12	
3652 Little Cottonwood Lane	0117-0-6"	0-6"	4	80		18	
3652 Little Cottonwood Lane	0118-6-12"	6-12"	4	170		25	
3652 Little Cottonwood Lane	0119-12-18"	12-18"	4	67		10	
3626 Little Cottonwood Lane	0122-0-6"	0-6"	1	57		9	
3626 Little Cottonwood Lane	0123-6-12"	6-12"	1	230		21	
3626 Little Cottonwood Lane	0124-12-18"	12-18"	1	350		29	
3626 Little Cottonwood Lane	0128-0-6"	0-6"	2	71		11	
3626 Little Cottonwood Lane	0129-6-12"	6-12"	2	140		17	
3626 Little Cottonwood Lane	0130-12-18"	12-18"	2	480		34	
3626 Little Cottonwood Lane	0131-0-6"	0-6"	3	28		8	
3626 Little Cottonwood Lane	0132-6-12"	6-12"	3	18		9	
3626 Little Cottonwood Lane	0133-12-18"	12-18"	3	31		8	
3626 Little Cottonwood Lane	0134-0-6"	0-6"	4	1300		70	
3626 Little Cottonwood Lane	0135-6-12"	6-12"	4	1200		71	
3626 Little Cottonwood Lane	0136-12-18"	12-18"	4	76		16	
3623 Little Cottonwood Lane	0158-0-6"	0-6"	1	94		8	
3623 Little Cottonwood Lane	0159-6-12"	6-12"	1	100		8	
3623 Little Cottonwood Lane	0160-12-18"	12-18"	1	99		9	
3623 Little Cottonwood Lane	0161-0-6"	0-6"	2	120		12	
3623 Little Cottonwood Lane	0162-6-12"	6-12"	2	320		19	
3623 Little Cottonwood Lane	0163-12-18"	12-18"	2	720		55	
3623 Little Cottonwood Lane	0164-0-6"	0-6"	play area	170		5	U
3623 Little Cottonwood Lane	0165-6-12"	6-12"	play area	90		5	
3623 Little Cottonwood Lane	0166-12-18"	12-18"	play area	120		8	
3623 Little Cottonwood Lane	0167-0-6"	0-6"	3	240		12	
3623 Little Cottonwood Lane	0168-6-12"	6-12"	3	510		31	
3623 Little Cottonwood Lane	0169-12-18"	12-18"	3	56		5	U
3623 Little Cottonwood Lane	0170-0-6"	0-6"	4	33		10	
3623 Little Cottonwood Lane	0171-6-12"	6-12"	4	27		6	
3623 Little Cottonwood Lane	0172-12-18"	12-18"	4	28		8	
3623 Little Cottonwood Lane	0173-0-6"	0-6"	5	310		14	
3623 Little Cottonwood Lane	0174-6-12"	6-12"	5	270		20	
3623 Little Cottonwood Lane	0175-12-18"	12-18"	5	28		10	
9795 Little Cottonwood Lane	0356-0-6"	0-6"	4	45		11	
9795 Little Cottonwood Lane	0357-6-12"	6-12"	4	800		37	
9795 Little Cottonwood Lane	0358-12-18"	12-18"	4	230		26	
9795 Little Cottonwood Lane	0359-0-6"	0-6"	3	93		13	
9795 Little Cottonwood Lane	0360-6-12"	6-12"	3	150		14	

Location	Sample Number	Depth	Zone	Lead (ppm)	Lead Q	Arsenic (ppm)	As Q
9795 Little Cottonwood Lane	0361-12-18"	12-18"	3	100		16	
9795 Little Cottonwood Lane	0362-0-6"	0-6"	2	51		13	
9795 Little Cottonwood Lane	0363-6-12"	6-12"	2	88		15	
9795 Little Cottonwood Lane	0364-12-18"	12-18"	2	79		11	
9795 Little Cottonwood Lane	0365-0-6"	0-6"	1	48		10	
9795 Little Cottonwood Lane	0366-6-12"	6-12"	1	160		15	
9795 Little Cottonwood Lane	0367-12-18"	12-18"	1	82		14	
9808 Little Cottonwood Lane	0372-0-6"	0-6"	1	57		12	
9808 Little Cottonwood Lane	0373-6-12"	6-12"	1	1700		48	
9808 Little Cottonwood Lane	0374-12-18"	12-18"	1	160		15	
9808 Little Cottonwood Lane	0375-0-6"	0-6"	2	250		17	
9808 Little Cottonwood Lane	0376-6-12"	6-12"	2	200		14	
9808 Little Cottonwood Lane	0377-12-18"	12-18"	2	250		19	
9808 Little Cottonwood Lane	0379-0-6"	0-6"	3	220		9	
9808 Little Cottonwood Lane	0380-6-12"	6-12"	3	200		16	
9808 Little Cottonwood Lane	0381-12-18"	12-18"	3	310		18	
9808 Little Cottonwood Lane	0387-0-6"	0-6"	4	3200		88	
9808 Little Cottonwood Lane	0388-6-12"	6-12"	4	2100		77	
9808 Little Cottonwood Lane	0389-12-18"	12-18"	4	3700		110	
9808 Little Cottonwood Lane	0390-0-6"	0-6"	5	1000		41	
9808 Little Cottonwood Lane	0391-6-12"	6-12"	5	1500		57	
9808 Little Cottonwood Lane	0392-12-18"	12-18"	5	1400		56	
9815 Little Cottonwood Lane	0393-0-6"	0-6"	1	300		16	
9815 Little Cottonwood Lane	0394-6-12"	6-12"	1	670		24	
9815 Little Cottonwood Lane	0395-12-18"	12-18"	1	3200		81	
9815 Little Cottonwood Lane	0396-0-6"	0-6"	2	260		11	
9815 Little Cottonwood Lane	0397-6-12"	6-12"	2	570		21	
9815 Little Cottonwood Lane	0398-12-18"	12-18"	2	780		16	
9815 Little Cottonwood Lane	0399-0-6"	0-6"	3	140		15	
9815 Little Cottonwood Lane	0400-6-12"	6-12"	3	230		23	
9815 Little Cottonwood Lane	0401-12-18"	12-18"	3	180		20	
9815 Little Cottonwood Lane	0403-0-6"	0-6"	4	110		8	
9815 Little Cottonwood Lane	0404-6-12"	6-12"	4	110		12	
9815 Little Cottonwood Lane	0405-12-18"	12-18"	4	160		12	
Slope on Little Cottonwood Lane	0894-0-6"	0-6"	1	190		11	
Slope on Little Cottonwood Lane	0895-6-12"	6-12"	1	190		14	
Slope on Little Cottonwood Lane	0896-12-18"	12-18"	1	230		14	
Slope on Little Cottonwood Lane	0898-0-6"	0-6"	2	440		28	
Slope on Little Cottonwood Lane	0899-6-12"	6-12"	2	420		32	
Slope on Little Cottonwood Lane	0900-12-18"	12-18"	2	220		20	
Slope on Little Cottonwood Lane	0904-0-6"	0-6"	3	340		17	
Slope on Little Cottonwood Lane	0905-6-12"	6-12"	3	430		23	
Slope on Little Cottonwood Lane	0907-12-18"	12-18"	3	350		20	
Slope on Little Cottonwood Lane	0908-0-6"	0-6"	4	920		31	
Slope on Little Cottonwood Lane	0909-6-12"	6-12"	4	2000		59	
Slope on Little Cottonwood Lane	0910-12-18"	12-18"	4	2300		63	
Slope on Little Cottonwood Lane	0911-0-6"	0-6"	5	950		33	
Slope on Little Cottonwood Lane	0912-6-12"	6-12"	5	880		30	
Slope on Little Cottonwood Lane	0913-12-18"	12-18"	5	640		26	
Slope on Little Cottonwood Lane	0915-0-6"	0-6"	6	1900		50	
Slope on Little Cottonwood Lane	0916-6-12"	6-12"	6	3000		69	
Slope on Little Cottonwood Lane	0917-12-18"	12-18"	6	4600		110	
Slope on Little Cottonwood Lane	0919-0-6"	0-6"	7	800		25	
Slope on Little Cottonwood Lane	0920-6-12"	6-12"	7	2400		67	
Slope on Little Cottonwood Lane	0921-12-18"	12-18"	7	4900		140	

Location	Sample Number	Depth	Zone	Lead (ppm)	Lead Q	Arsenic (ppm)	As Q
Slope on Little Cottonwood Lane	0923-0-6"	0-6"	8	4800		120	
Slope on Little Cottonwood Lane	0924-6-12"	6-12"	8	3600		92	
Slope on Little Cottonwood Lane	0925-12-18"	12-18"	8	3800		110	
3587 Little Cottonwood Lane	0926-0-6"	0-6"	1	53		10	
3587 Little Cottonwood Lane	0927-6-12"	6-12"	1	170		13	
3587 Little Cottonwood Lane	0928-12-18"	12-18"	1	540		22	
3587 Little Cottonwood Lane	0934-0-6"	0-6"	2	76		11	
3587 Little Cottonwood Lane	0935-6-12"	6-12"	2	69		9	
3587 Little Cottonwood Lane	0937-12-18"	12-18"	2	270		15	
3587 Little Cottonwood Lane	0938-0-6"	0-6"	3	1700		45	
3587 Little Cottonwood Lane	0939-6-12"	6-12"	3	2300		98	
3587 Little Cottonwood Lane	0940-12-18"	12-18"	3	1900		59	
3587 Little Cottonwood Lane	0941-0-6"	0-6"	4	1800		59	
3587 Little Cottonwood Lane	0942-6-12"	6-12"	4	2800		68	
3587 Little Cottonwood Lane	0943-12-18"	12-18"	4	1500		51	
3587 Little Cottonwood Lane	0944-0-6"	0-6"	5	280		15	
3587 Little Cottonwood Lane	0945-6-12"	6-12"	5	450		18	
3587 Little Cottonwood Lane	0946-12-18"	12-18"	5	1000		35	

APPENDIX 3 RAW DATA FOR INDOOR DUST

Residence	Sample Number	Lead (mg/<150 µm Sample)	Total Particulate (g)	<150 um Particulate (g)	ppm
9764 Little Cottonwood Place	V-01-01-002	0.48	4.15	2.39	200.83682
9764 Little Cottonwood Place	V-06-02-003	0.21	1.72	1.27	165.35433
9764 Little Cottonwood Place	V-07-03-004	0.0028	0.414	0.043	65.116279
3698 Little Cottonwood Lane	V-013-01-009	0.08	1.65	1.3	61.538462
3698 Little Cottonwood Lane	V-016-02-010	0.069	1.17	1.03	66.990291
3698 Little Cottonwood Lane	V-019-03-011	0.00056	0.0327	0.0145	38.62069
9687 Quail Ridge Road	V-025-01-012	0.048	1.16	0.602	79.734219
9687 Quail Ridge Road	V-028-02-013	0.039	1.21	0.677	57.60709
9687 Quail Ridge Road	V-031-03-014	0.0034	0.168	0.104	32.692308
9712 Quail Ridge Road	V-037-01-006	0.028	0.317	0.156	179.48718
9712 Quail Ridge Road	V-040-02-005	0.013	0.131	0.0756	171.95767
9712 Quail Ridge Road	V-043-03-007	0.005	0.224	0.0626	79.872204
9767 Little Cottonwood Place	V-048-01-008	0.032	0.64	0.539	59.369202
9767 Little Cottonwood Place	V-051-02-017	0.0017	0.0658	0.0533	31.894934
9767 Little Cottonwood Place	V-055-03-019	0.13	2.13	1.41	92.198582
3660 N. Little Cottonwood Road	V-060-01-015	0.71	4.93	3.53	201.13314
3660 N. Little Cottonwood Road	V-064-02-018	0.028	0.239	0.138	202.89855
3660 N. Little Cottonwood Road	V-068-03-020	0.011	0.0994	0.049	224.4898
01 Little Cottonwood Canyon Road (Alta Academ	V-072-01-016	0.22	2.98	2.21	99.547511
01 Little Cottonwood Canyon Road (Alta Academ	V-076-02-021	0.15	1.13	0.822	182.48175
01 Little Cottonwood Canyon Road (Alta Academ	V-080-03-029	0.14	2.85	0.831	168.47172
01 Little Cottonwood Canyon Road (Alta Academ	V-084-04-057	14	3.41	2.06	6796.1165
01 Little Cottonwood Canyon Road (Alta Academ	V-091-05-022	0.03	0.375	0.175	171.42857
SAIC	V-092-01-061	0.054	0.623	0.404	133.66337
3626 Little Cottonwood Lane	V-096-01-030	0.041	0.782	0.517	79.303675
3626 Little Cottonwood Lane	V-100-02-058	0.004	0.0545	0.055	72.727273
3626 Little Cottonwood Lane	V-104-03-039	0.00088	0.0323	0.017	51.764706
3695 Little Cottonwood Lane	V-107-01-040	0.084	1.7	1.256	66.878981
3695 Little Cottonwood Lane	V-111-02-050	0.36	4.51	3.54	101.69492
3695 Little Cottonwood Lane	V-114-03-031	0.023	0.384	0.256	89.84375
3710 N. Little Cottonwood Road	V-118-01-024	0.063	0.851	0.453	139.07285
3710 N. Little Cottonwood Road	V-122-02-025	0.00042	0.0276	0.0127	33.070866
3710 N. Little Cottonwood Road	V-126-03-026	0.29	3.63	2.82	102.83688
9650 Glacier Lane	V-130-01-051	0.15	2.18	1.72	87.209302
9650 Glacier Lane	V-134-02-033	0.2	1.41	1.18	169.49153
9650 Glacier Lane	V-138-03-065	0.056	0.521	0.411	136.25304

1.0 EXPOSURE VIA INHALATION OF PARTICULATES IN AIR

The basic equation recommended by EPA (1989a) for evaluation of inhalation exposure is:

$$DI_{air} = C_a \cdot BR_a \cdot EF \cdot ED/(BW \cdot AT)$$

where:

DI_{air}	=	Daily intake from air (mg/kg-d)
C_a	=	Concentration of substance in air (mg/m^3)
BR_a	=	Breathing rate of air (m^3/day)
EF	=	Exposure frequency (days/yr)
ED	=	Exposure duration (yrs)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

Recommended data defaults are as summarized below.

Parameter	Source Documents	Typical RME Values for Residential Adult[a]
BR	RAGS (EPA 1989b)	20 m^3/day
EF	RAGS Supplemental Guidance (EPA 1991)	350 days/yr
ED	RAGS Supplemental Guidance (EPA 1991)	30 years
BW	RAGS (EPA 1989b)	70 kg
AT	RAGS (EPA 1989b) RAGS Supplemental Guidance (EPA 1991)	30 years (noncancer) 70 years (cancer)

The relative magnitude of the inhaled dose of arsenic and lead from air can be compared to the ingested dose from soil as follows:

$$\frac{DI_{air}}{DI_{oral}} = \frac{C_{air} \cdot BR_a}{C_s \cdot IR_s}$$

where:

DI_{air}	=	Daily intake from air (mg/kg-d)
C_a	=	Concentration of substance in air (mg/m^3)
BR_a	=	Breathing rate of air (m^3/day)
C_s	=	Concentration in soil
IR_s	=	Ingestion rate of soil (kg/day)

The EPA recommends a screening level soil to air transfer factor of 7.6E-10 kg/m^3 (EPA 1996) and a soil ingestion rate by adults of 100 mg/day (1E-04 kg/day) (EPA 1991b). Based on these values, the ratio of the mass of soil inhaled to that ingested is:

$$\frac{DI_{air}}{DI_{oral}} = \frac{7.6E-10\ kg/m^3 \cdot 20\ m^3/day}{1E-04\ kg/day} = 1.5E-05\ (0.015\%)$$

As seen, the inhaled dose of soil is very small compared to the ingested dose, so the inhalation pathway is not considered to be of significant concern at this site.

2.0 DERMAL EXPOSURE VIA WATER

The basic equation recommended by EPA (1989a, 1992) for evaluation of dermal exposure to water based on this model is:

$$AD_w = C_w \cdot SA \cdot PC \cdot t \cdot EF \cdot ED/(BW \cdot AT)$$

where:

AD_w	=	Absorbed dose from water (mg/kg-d)
C_w	=	Concentration of chemical in water (mg/cm^3)
SA	=	Surface area exposed (cm^2)
PC	=	Chemical-specific permeability constant (cm/hr)
t	=	Exposure time (hr/event)
EF	=	Exposure frequency (days/yr)
ED	=	Exposure duration (yrs)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

Recommended data defaults are as summarized below.

Parameter	Source Documents	Typical RME Values for Residential Adult[a]
SA	Dermal Exposure Guidance (EPA 1992) Exposure Factors Handbook (EPA 1989a)	20,000 cm^2
PC	Dermal Exposure Guidance (EPA 1992)	Chemical specific
t	RAGS (EPA 1989b) Exposure Factors Handbook (EPA 1989a) Dermal Exposure Guidance (EPA 1992)	12 minutes
EF	Dermal Exposure Guidance (EPA 1992) RAGS Supplemental Guidance (EPA 1991)	350 days/yr
ED	Dermal Exposure Guidance (EPA 1992) RAGS Supplemental Guidance (EPA 1991)	30 years
BW	RAGS (EPA 1989b) RAGS Supplemental Guidance (EPA 1991)	70 kg
AT	RAGS (EPA 1989b) RAGS Supplemental Guidance (EPA 1991)	30 years (noncancer) 70 years (cancer)

[a] Values shown are for the bathing/showering pathway. Other values may be applicable for scenarios such as wading or swimming.

For a residential population exposed to water-borne contaminants by both ingestion and dermal contact via the showering/bathing scenario, the relative magnitude of the absorbed dose following dermal exposure to water (AD_d) and oral (ingestion) exposure (AD_o) to water is given by:

$$\frac{AD_d}{AD_o} = \frac{SA \cdot PC \cdot t}{IR_w \cdot AF_o}$$

where:

SA	=	Surface area exposed (cm^2)
PC	=	Chemical-specific permeability constant (cm/hr)
t	=	Exposure time (hr/day)
IR_w	=	Ingestion rate of water (cm^3/day)
AF_o	=	Oral absorption fraction

Incorporating representative values for the whole-body surface area of an adult (20,000 cm^2) and for time spent bathing or showering (0.2 hr), and assuming a water ingestion rate of 2 L/day (2,000 cm^3/day), yields the following:

$$\frac{AD_d}{AD_o} = \frac{2 \cdot PC}{AF_o}$$

For lead and arsenic, measured and recommended default values of AF_o and PC are listed below, along with the calculated ratio of absorbed doses (AD_d/AD_o):

Chemical	PC (cm/hr)	AF_o	AD_d/AD_o
Lead	4E-06[a]	0.10[c]	8E-05
Arsenic	1E-03[b]	1.0[c]	2E-03

[a] Measured value (USEPA 1992)
[b] USEPA (1992) recommends a default value of 1E-03 cm/hr for inorganics for which data are not available
[c] Owen (1990)

As seen, the ratio of dermal to oral absorbed dose is quite small for both lead (0.08%) and arsenic (0.2%). Based on this, it is concluded that the dose contributed by the dermal pathway is likely to be sufficiently minor compared to the ingestion pathway that it need not be quantified for the residential population.

3.0 DERMAL EXPOSURE VIA SOIL

The basic equation recommended for estimation of dermal dose from contact with soils is as follows (EPA 1989b, 1992):

$$AD_{soil} = C_s \cdot SA \cdot AF \cdot ABS \cdot EF \cdot ED/(BW \cdot AT)$$

where:

C_s	=	concentration of chemical in soil (mg/kg)
SA	=	surface area in contact with soil (cm^2)
AF	=	soil adherence factor (kg/cm^2)
ABS	=	absorption fraction (unitless)

At the present time, data are very limited on the value of the ABS term, and the EPA (1992) has concluded that there are only three chemicals for which sufficient data exist to estimate credible ABS values, as shown below:

Chemical	ABS

Dioxins	0.1-3%
PCBs	0.6-6%
Cadmium	0.1-1%

It is important to realize that even these values are rather uncertain, due to a variety of differences between the exposure conditions used in laboratory studies of dermal absorption and exposure conditions that are likely to occur at Superfund sites. For example, most laboratory studies use much higher soil loadings on the skin (e.g., 5-50 mg/cm^2) than are expected to occur at sites (0.2-1 mg/cm^2). Also, most studies investigate the amount absorbed after a relatively lengthy contact period (16-96 hours), while it is expected that most people would wash off soil on the skin more promptly than this. Because of these difficulties in extrapolation from experimental measurements to "real-life" conditions, the values above are only considered approximate, and are more likely to be high than low. With respect to estimating ABS values for other chemicals (those for which there are no reliable experimental measurements), the EPA concludes that current methods are not sufficiently developed to calculate values from available data such as physical-chemical properties.

If values of ABS were available for lead and arsenic, the relative magnitude of the dermal dose to the oral dose would be calculated as follows:

$$\frac{AD_d}{AD_o} = \frac{SA \cdot AF \cdot ABS \cdot EF_d}{IR \cdot AF_o \cdot EF_o}$$

where:

SA	=	surface area in contact with soil (cm^2)
AF	=	soil adherence factor (kg/cm^2)
ABS	=	absorption fraction (unitless)
IR_w	=	Ingestion rate of water (cm^3/day)
AF_o	=	Oral absorption fraction
EF_d	=	Dermal exposure frequency (days/yr)
EF_o	=	Dermal exposure frequency (days/yr)

Assuming that 10% of the body area (2,000 cm^2) is covered with soil (1 mg/cm^2 = 1E-06 kg/cm^2) for 50 days/yr, the ratio of the predicted dermal absorbed dose to the oral absorbed dose is given by:

$$\frac{AD_d}{AD_o} = 2.86\ \frac{ABS}{AF_o}$$

If, by extrapolation from cadmium, ABS is assumed to be 0.1-1% for lead and arsenic, then the ratio of dermal dose from soil to oral dose from soil are as follows:

Chemical	ABS (assumed)	AFo	Dose Ratio (dermal/oral)
Arsenic	0.001-0.01	1	0.3-3%
Lead	0.001-0.01	0.1	3-28%

Because the value of ABS is not available for lead or arsenic, these values should not be considered to be reliable. However, this calculation does support the conclusion that dermal absorption of lead and arsenic from dermal contact with soil is likely to be relatively minor compared to the oral pathway, and omission of this pathway is not likely to lead to a substantial underestimate of exposure or risk.

4.0 REFERENCES

EPA. 1989a. Exposure Factors Handbook. Office of Health and Environmental Assessment, Washington, DC. EPA/600/8-89/043.

EPA. 1989b. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual Part A. Interim Final. Office of Solid Waste and Emergency Response (OSWER), Washington, DC. OSWER Directive 9285.701A.

EPA. 1991a. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary remediation Goals). Interim. Office of Research and Development, Washington, DC. EPA/540/R-92-003.

EPA. 1991b. "Standard Default Exposure Factors." Supplemental Guidance for Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual. OERR, Washington, DC. OSWER Directive 9285.6-03.

EPA. 1992. Dermal Exposure Assessment: Principles and Applications. Interim Report. Office of Research and Development, Washington, DC. EPA/600/8-91/011B.

EPA. 1996. Soil Screening Guidance: User's Guide. Office of Solid Waste and Emergency Response, Washington DC. Publication 9355.4-23. July 1996.

Owen BA. 1990. Literature-derived Absorption Coefficients for 39 Chemicals via Oral and Inhalation Routes of Exposure. Reg. Toxicol. Pharmacol. 11:237-252.

APPENDIX 4 SCREENING LEVEL EVALUATION OF RELATIVE RISK FROM INHALATION OF DUST AND DERMAL CONTACT WITH SOIL OR WATER

1.0 EXPOSURE VIA INHALATION OF PARTICULATES IN AIR

The basic equation recommended by EPA (1989a) for evaluation of inhalation exposure is:

$$DI_{air} = C_a \cdot BR_a \cdot EF \cdot ED/(BW \cdot AT)$$

where:

DI_{air}	=	Daily intake from air (mg/kg-d)
C_a	=	Concentration of substance in air (mg/m^3)
BR_a	=	Breathing rate of air (m^3/day)
EF	=	Exposure frequency (days/yr)
ED	=	Exposure duration (yrs)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

Recommended data defaults are as summarized below.

Parameter	Source Documents	Typical RME Values for Residential Adult[a]
BR	RAGS (EPA 1989b)	20 m^3/day
EF	RAGS Supplemental Guidance (EPA 1991)	350 days/yr
ED	RAGS Supplemental Guidance (EPA 1991)	30 years
BW	RAGS (EPA 1989b)	70 kg
AT	RAGS (EPA 1989b) RAGS Supplemental Guidance (EPA 1991)	30 years (noncancer) 70 years (cancer)

The relative magnitude of the inhaled dose of arsenic and lead from air can be compared to the ingested dose from soil as follows:

$$\frac{DI_{air}}{DI_{oral}} = \frac{C_{air} \cdot BR_a}{C_s \cdot IR_s}$$

where:

DI_{air}	=	Daily intake from air (mg/kg-d)
C_a	=	Concentration of substance in air (mg/m^3)
BR_a	=	Breathing rate of air (m^3/day)
C_s	=	Concentration in soil
IR_s	=	Ingestion rate of soil (kg/day)

The EPA recommends a screening level soil to air transfer factor of 7.6E-10 kg/m^3 (EPA 1996) and a soil ingestion rate by adults of 100 mg/day (1E-04 kg/day) (EPA 1991b). Based on these values, the ratio of the mass of soil inhaled to that ingested is:

$$\frac{DI_{air}}{DI_{oral}} = \frac{7.6E-10\ kg/m^3 \cdot 20\ m^3/day}{1E-04\ kg/day} = 1.5E-05\ (0.015\%)$$

As seen, the inhaled dose of soil is very small compared to the ingested dose, so the inhalation pathway is not considered to be of significant concern at this site.

2.0 DERMAL EXPOSURE VIA WATER

The basic equation recommended by EPA (1989a, 1992) for evaluation of dermal exposure to water based on this model is:

$$AD_w = C_w \cdot SA \cdot PC \cdot t \cdot EF \cdot ED/(BW \cdot AT)$$

where:

AD_w	=	Absorbed dose from water (mg/kg-d)
C_w	=	Concentration of chemical in water (mg/cm^3)
SA	=	Surface area exposed (cm^2)
PC	=	Chemical-specific permeability constant (cm/hr)
t	=	Exposure time (hr/event)
EF	=	Exposure frequency (days/yr)
ED	=	Exposure duration (yrs)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

Recommended data defaults are as summarized below.

Parameter	Source Documents	Typical RME Values for Residential Adult[a]
SA	Dermal Exposure Guidance (EPA 1992) Exposure Factors Handbook (EPA 1989a)	20,000 cm^2
PC	Dermal Exposure Guidance (EPA 1992)	Chemical specific
t	RAGS (EPA 1989b) Exposure Factors Handbook (EPA 1989a) Dermal Exposure Guidance (EPA 1992)	12 minutes
EF	Dermal Exposure Guidance (EPA 1992) RAGS Supplemental Guidance (EPA 1991)	350 days/yr
ED	Dermal Exposure Guidance (EPA 1992) RAGS Supplemental Guidance (EPA 1991)	30 years
BW	RAGS (EPA 1989b) RAGS Supplemental Guidance (EPA 1991)	70 kg
AT	RAGS (EPA 1989b) RAGS Supplemental Guidance (EPA 1991)	30 years (noncancer) 70 years (cancer)

[a] Values shown are for the bathing/showering pathway. Other values may be applicable for scenarios such as wading or swimming.

For a residential population exposed to water-borne contaminants by both ingestion and dermal contact via the showering/bathing scenario, the relative magnitude of the absorbed dose following dermal exposure to water (AD_d) and oral (ingestion) exposure (AD_o) to water is given by:

$$\frac{AD_d}{AD_o} = \frac{SA \cdot PC \cdot t}{IR_w \cdot AF_o}$$

where:

SA	=	Surface area exposed (cm^2)
PC	=	Chemical-specific permeability constant (cm/hr)
t	=	Exposure time (hr/day)
IR_w	=	Ingestion rate of water (cm^3/day)
AF_o	=	Oral absorption fraction

Incorporating representative values for the whole-body surface area of an adult (20,000 cm^2) and for time spent bathing or showering (0.2 hr), and assuming a water ingestion rate of 2 L/day (2,000 cm^3/day), yields the following:

$$\frac{AD_d}{AD_o} = \frac{2 \cdot PC}{AF_o}$$

For lead and arsenic, measured and recommended default values of AF_o and PC are listed below, along with the calculated ratio of absorbed doses (AD_d/AD_o):

Chemical	PC (cm/hr)	AF_o	AD_d/AD_o
Lead	4E-06[a]	0.10[c]	8E-05
Arsenic	1E-03[b]	1.0[c]	2E-03

[a] Measured value (USEPA 1992)
[b] USEPA (1992) recommends a default value of 1E-03 cm/hr for inorganics for which data are not available
[c] Owen (1990)

As seen, the ratio of dermal to oral absorbed dose is quite small for both lead (0.08%) and arsenic (0.2%). Based on this, it is concluded that the dose contributed by the dermal pathway is likely to be sufficiently minor compared to the ingestion pathway that it need not be quantified for the residential population.

3.0 DERMAL EXPOSURE VIA SOIL

The basic equation recommended for estimation of dermal dose from contact with soils is as follows (EPA 1989b, 1992):

$$AD_{soil} = C_s \cdot SA \cdot AF \cdot ABS \cdot EF \cdot ED/(BW \cdot AT)$$

where:

C_s	=	concentration of chemical in soil (mg/kg)
SA	=	surface area in contact with soil (cm^2)
AF	=	soil adherence factor (kg/cm^2)
ABS	=	absorption fraction (unitless)

At the present time, data are very limited on the value of the ABS term, and the EPA (1992) has concluded that there are only three chemicals for which sufficient data exist to estimate credible ABS values, as shown below:

Chemical	ABS

Dioxins	0.1-3%
PCBs	0.6-6%
Cadmium	0.1-1%

It is important to realize that even these values are rather uncertain, due to a variety of differences between the exposure conditions used in laboratory studies of dermal absorption and exposure conditions that are likely to occur at Superfund sites. For example, most laboratory studies use much higher soil loadings on the skin (e.g., 5-50 mg/cm^2) than are expected to occur at sites (0.2-1 mg/cm^2). Also, most studies investigate the amount absorbed after a relatively lengthy contact period (16-96 hours), while it is expected that most people would wash off soil on the skin more promptly than this. Because of these difficulties in extrapolation from experimental measurements to "real-life" conditions, the values above are only considered approximate, and are more likely to be high than low. With respect to estimating ABS values for other chemicals (those for which there are no reliable experimental measurements), the EPA concludes that current methods are not sufficiently developed to calculate values from available data such as physical-chemical properties.

If values of ABS were available for lead and arsenic, the relative magnitude of the dermal dose to the oral dose would be calculated as follows:

$$\frac{AD_d}{AD_o} = \frac{SA \cdot AF \cdot ABS \cdot EF_d}{IR \cdot AF_o \cdot EF_o}$$

where:

SA	=	surface area in contact with soil (cm^2)
AF	=	soil adherence factor (kg/cm^2)
ABS	=	absorption fraction (unitless)
IR_w	=	Ingestion rate of water (cm^3/day)
AF_o	=	Oral absorption fraction
EF_d	=	Dermal exposure frequency (days/yr)
EF_o	=	Dermal exposure frequency (days/yr)

Assuming that 10% of the body area (2,000 cm^2) is covered with soil (1 mg/cm^2 = 1E-06 kg/cm^2) for 50 days/yr, the ratio of the predicted dermal absorbed dose to the oral absorbed dose is given by:

$$\frac{AD_d}{AD_o} = 2.86\ \frac{ABS}{AF_o}$$

If, by extrapolation from cadmium, ABS is assumed to be 0.1-1% for lead and arsenic, then the ratio of dermal dose from soil to oral dose from soil are as follows:

Chemical	ABS (assumed)	AFo	Dose Ratio (dermal/oral)
Arsenic	0.001-0.01	1	0.3-3%
Lead	0.001-0.01	0.1	3-28%

Because the value of ABS is not available for lead or arsenic, these values should not be considered to be reliable. However, this calculation does support the conclusion that dermal absorption of lead and arsenic from dermal contact with soil is likely to be relatively minor compared to the oral pathway, and omission of this pathway is not likely to lead to a substantial underestimate of exposure or risk.

4.0 REFERENCES

EPA. 1989a. Exposure Factors Handbook. Office of Health and Environmental Assessment, Washington, DC. EPA/600/8-89/043.

EPA. 1989b. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual Part A. Interim Final. Office of Solid Waste and Emergency Response (OSWER), Washington, DC. OSWER Directive 9285.701A.

EPA. 1991a. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary remediation Goals). Interim. Office of Research and Development, Washington, DC. EPA/540/R-92-003.

EPA. 1991b. "Standard Default Exposure Factors." Supplemental Guidance for Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual. OERR, Washington, DC. OSWER Directive 9285.6-03.

EPA. 1992. Dermal Exposure Assessment: Principles and Applications. Interim Report. Office of Research and Development, Washington, DC. EPA/600/8-91/011B.

EPA. 1996. Soil Screening Guidance: User's Guide. Office of Solid Waste and Emergency Response, Washington DC. Publication 9355.4-23. July 1996.

Owen BA. 1990. Literature-derived Absorption Coefficients for 39 Chemicals via Oral and Inhalation Routes of Exposure. Reg. Toxicol. Pharmacol. 11:237-252.

APPENDIX 5 SPECIATION DATA

SUMMARY STATISTICS
3587-931 - Arsenic

	COUNTS		SIZE			Count Freq (%)		LW Freq (%)				Relative Arsenic Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract As	Total	Liberated
Pb Barite	2	2	3	3	3	2.7%	2.7%	1.20%	1.20%	4	0	0.0%	0.0%
Fe Oxide	28	28	9	2	48	37.3%	37.3%	48.90%	48.90%	4	0.0064	28.3%	28.3%
Mn Oxide	17	17	9	3	26	22.7%	22.7%	29.94%	29.94%	5	0.0014	4.7%	4.7%
PbAsO	2	2	5	4	6	2.7%	2.7%	2.00%	2.00%	7.1	0.16	51.2%	51.2%
PbMO	1	1	8	8	8	1.3%	1.3%	1.60%	1.60%	7.1	0.03	0.0%	0.0%
PbSiO4	1	1	2	2	2	1.3%	1.3%	0.40%	0.40%	6	0	0.0%	0.0%
Phosphate	23	22	3	1	22	30.7%	29.3%	13.57%	13.17%	5	0.0044	6.7%	6.5%
Fe Sulfate	1	1	12	12	12	1.3%	1.3%	2.40%	2.40%	3.7	0.045	9.0%	9.0%
TOTAL	75	74	7			100.0%	98.7%	100.00%	99.60%			100.0%	99.8%

DISTRIBUTION				
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	60.0%	58.7%	26.9%	26.7%
5-9	20.0%	20.0%	42.8%	42.8%
10-19	13.3%	13.3%	17.4%	17.4%
20-49	6.7%	6.7%	12.9%	12.9%
50-99	0.0%	0.0%	0.0%	0.0%
100-149	0.0%	0.0%	0.0%	0.0%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	99%	100%	100%

SUMMARY STATISTICS
3587-931 - Lead

	COUNTS			SIZE		Count Freq (%)		LW Freq (%)				Relative Lead Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract Pb	Total	Liberated
Pb Barite	2	2	3	3	3	2.7%	2.7%	1.20%	1.20%	4	0.057	0.4%	0.4%
Fe Oxide	28	28	9	2	48	37.3%	37.3%	48.90%	48.90%	4	0.06	17.0%	17.0%
Mn Oxide	17	17	9	3	26	22.7%	22.7%	29.94%	29.94%	5	0.13	28.1%	28.1%
PbAsO	2	2	5	4	6	2.7%	2.7%	2.00%	2.00%	7.1	0.55	11.3%	11.3%
PbMO	1	1	8	8	8	1.3%	1.3%	1.60%	1.60%	7.1	0.34	0.0%	0.0%
PbSiO4	1	1	2	2	2	1.3%	1.3%	0.40%	0.40%	6	0.5	0.0%	0.0%
Phosphate	23	22	3	1	22	30.7%	29.3%	13.57%	13.17%	5	0.418	41.0%	39.8%
Fe Sulfate	1	1	12	12	12	1.3%	1.3%	2.40%	2.40%	3.7	0.18	2.3%	2.3%
TOTAL	75	74	7			100.0%	98.7%	100.00%	99.60%			100.0%	98.8%

	DISTRIBUTION			
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	60.0%	58.7%	30.0%	28.9%
5-9	20.0%	20.0%	23.7%	23.7%
10-19	13.3%	13.3%	19.7%	19.7%
20-49	6.7%	6.7%	26.6%	26.6%
50-99	0.0%	0.0%	0.0%	0.0%
100-149	0.0%	0.0%	0.0%	0.0%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	99%	100%	99%

MINERAL FREQUENCY OBSERVED IN SITE SOIL

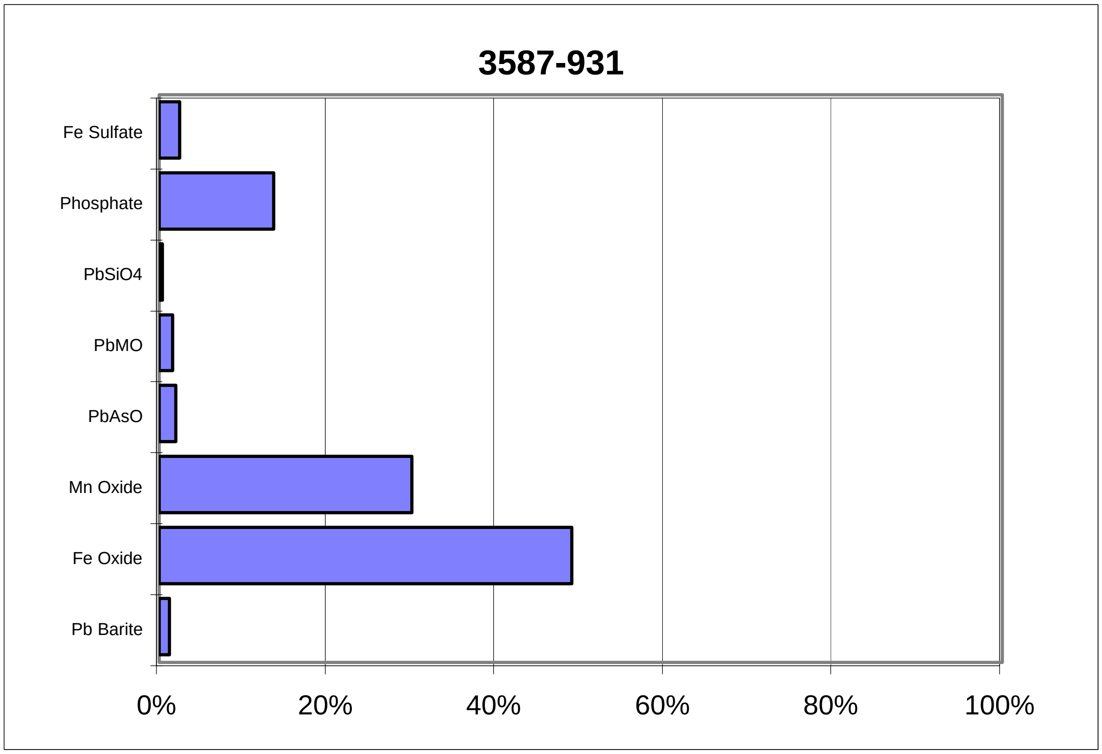
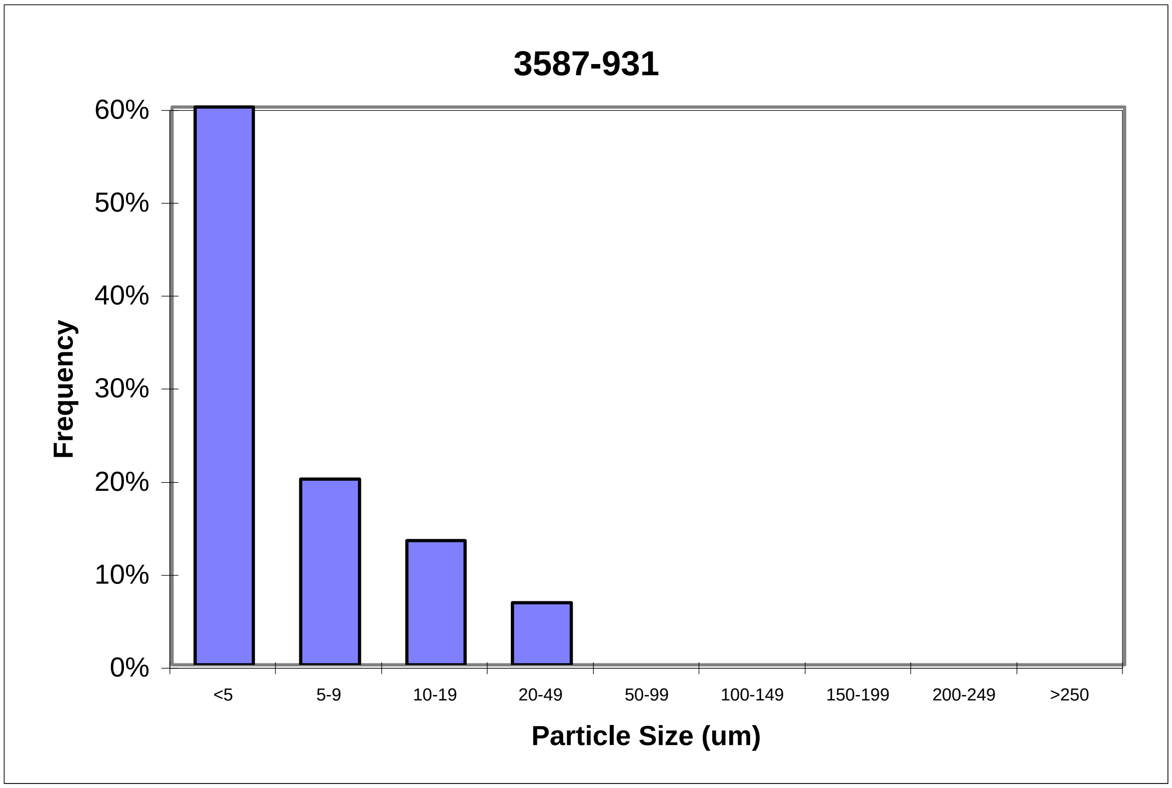
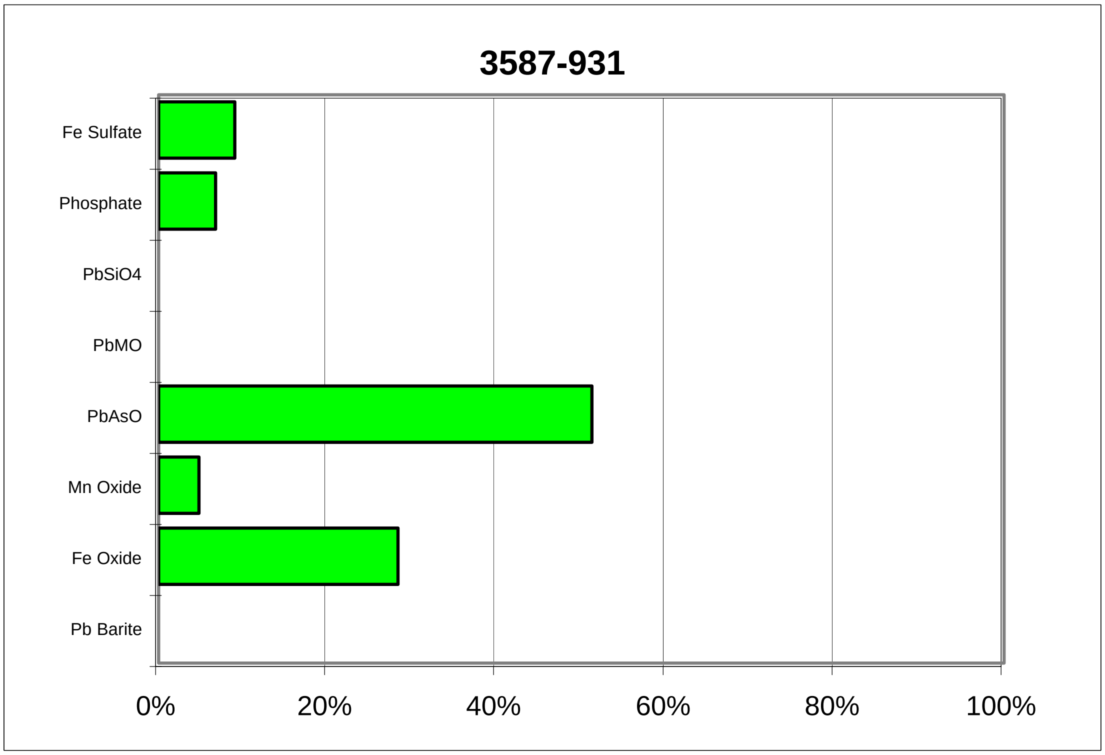


FIGURE 1 PARTICLE SIZE DISTRIBUTION



RELATIVE ARSENIC MASS



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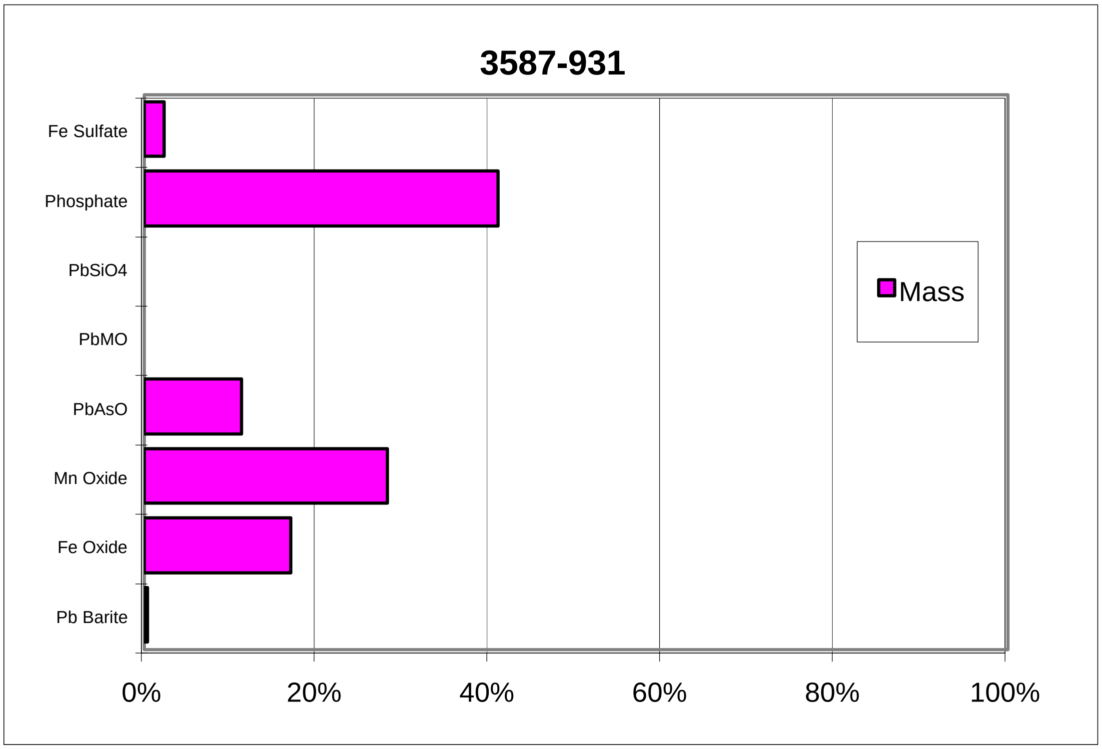


	3587-931 - As		3587-931 - Pb	
Mineral	Freq	Mass	Freq	Mass
Pb Barite	1.2%	0.00%	1.2%	0.4%
Fe Oxide	48.9%	28.28%	48.9%	17.0%
Mn Oxide	29.9%	4.73%	29.9%	28.1%
PbAsO	2.0%	51.23%	2.0%	11.3%
PbMO	1.6%	0.00%	1.6%	0.0%
PbSiO4	0.4%	0.00%	0.4%	0.0%
Phosphate	13.6%	6.75%	13.6%	41.0%
Fe Sulfate	2.4%	9.01%	2.4%	2.3%

Size	3587-931 - As	3587-931 - Pb
<5	60.0%	60.0%
5-9	20.0%	20.0%
10-19	13.3%	13.3%
20-49	6.7%	6.7%
50-99	0.0%	0.0%
100-149	0.0%	0.0%
150-199	0.0%	0.0%
200-249	0.0%	0.0%
≥250	0.0%	0.0%

SUMMARY STATISTICS
3601-805 - Arsenic

	COUNTS			SIZE		Count Freq (%)		LW Freq (%)				Relative Arsenic Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract As	Total	Liberated
AsFeO	2	2	15	10	20	1.7%	1.7%	2.51%	2.51%	4.5	0.16	31.9%	31.9%
Fe Oxide	44	44	14	2	60	38.3%	38.3%	53.05%	53.05%	4	0.0046	17.2%	17.2%
Mn Oxide	36	36	9	1	110	31.3%	31.3%	25.65%	25.65%	5	0.0014	3.2%	3.2%
PbAsO	3	3	4	3	7	2.6%	2.6%	1.09%	1.09%	7.1	0.16	21.8%	21.8%
PbMO	4	4	1	1	1	3.5%	3.5%	0.33%	0.33%	7.1	0.03	1.3%	1.3%
Phosphate	16	16	8	1	59	13.9%	13.9%	10.36%	10.36%	5	0.0044	4.0%	4.0%
Fe Sulfate	10	10	8	2	40	8.7%	8.7%	7.02%	7.02%	3.7	0.045	20.6%	20.6%
TOTAL	115	115	10			100.0%	100.0%	100.00%	100.00%			100.0%	100.0%

DISTRIBUTION				
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	50.4%	50.4%	18.1%	18.1%
5-9	15.7%	15.7%	15.2%	15.2%
10-19	18.3%	18.3%	19.8%	19.8%
20-49	13.0%	13.0%	41.9%	41.9%
50-99	1.7%	1.7%	4.0%	4.0%
100-149	0.9%	0.9%	1.0%	1.0%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	100%	100%	100%

SUMMARY STATISTICS
ND-98-114 - Lead

	COUNTS			SIZE		Count Freq (%)		LW Freq (%)				Relative Lead Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract Pb	Total	Liberated
AsFeO	2	2	15	10	20	1.7%	1.7%	2.51%	2.51%	4.5	0.073	1.3%	1.3%
Fe Oxide	44	44	14	2	60	38.3%	38.3%	53.05%	53.05%	4	0.06	20.7%	20.7%
Mn Oxide	36	36	9	1	110	31.3%	31.3%	25.65%	25.65%	5	0.13	27.1%	27.1%
PbAsO	3	3	4	3	7	2.6%	2.6%	1.09%	1.09%	7.1	0.55	6.9%	6.9%
PbMO	4	4	1	1	1	3.5%	3.5%	0.33%	0.33%	7.1	0.34	1.3%	1.3%
Phosphate	16	16	8	1	59	13.9%	13.9%	10.36%	10.36%	5	0.418	35.1%	35.1%
Fe Sulfate	10	10	8	2	40	8.7%	8.7%	7.02%	7.02%	3.7	0.18	7.6%	7.6%
TOTAL	115	115	10			100.0%	100.0%	100.00%	100.00%			100.0%	100.0%

	DISTRIBUTION			
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	50.4%	50.4%	16.5%	16.5%
5-9	15.7%	15.7%	12.7%	12.7%
10-19	18.3%	18.3%	20.2%	20.2%
20-49	13.0%	13.0%	24.0%	24.0%
50-99	1.7%	1.7%	17.8%	17.8%
100-149	0.9%	0.9%	8.8%	8.8%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	100%	100%	100%

MINERAL FREQUENCY OBSERVED IN SITE SOIL

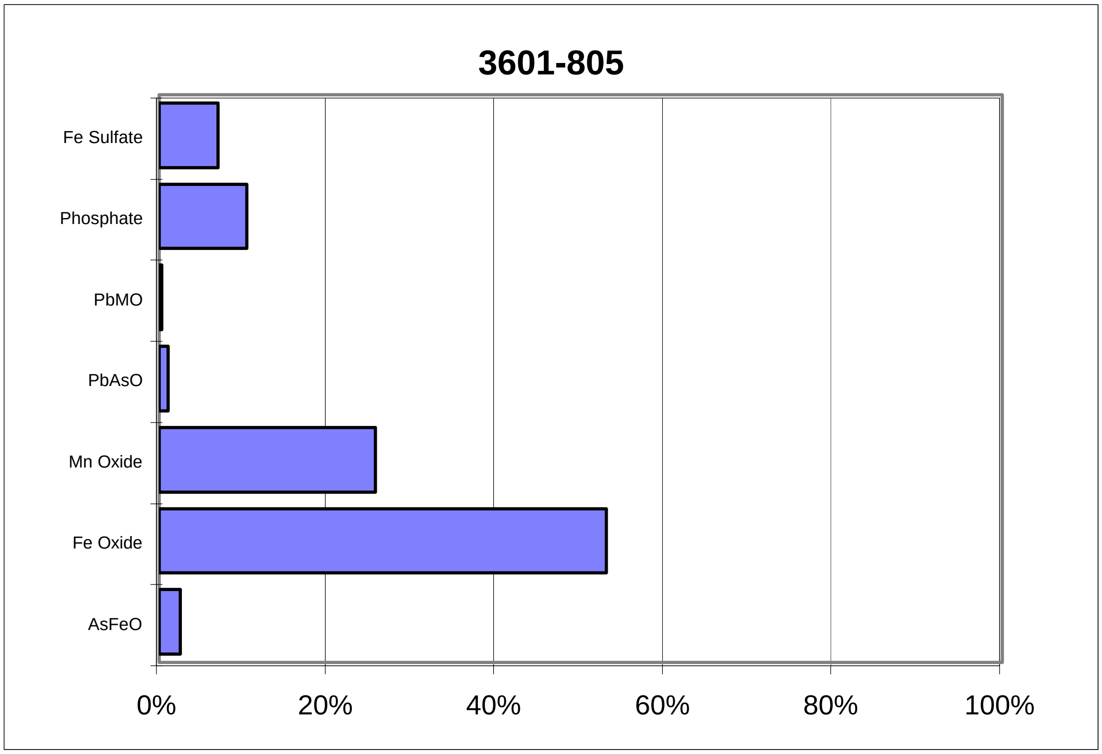
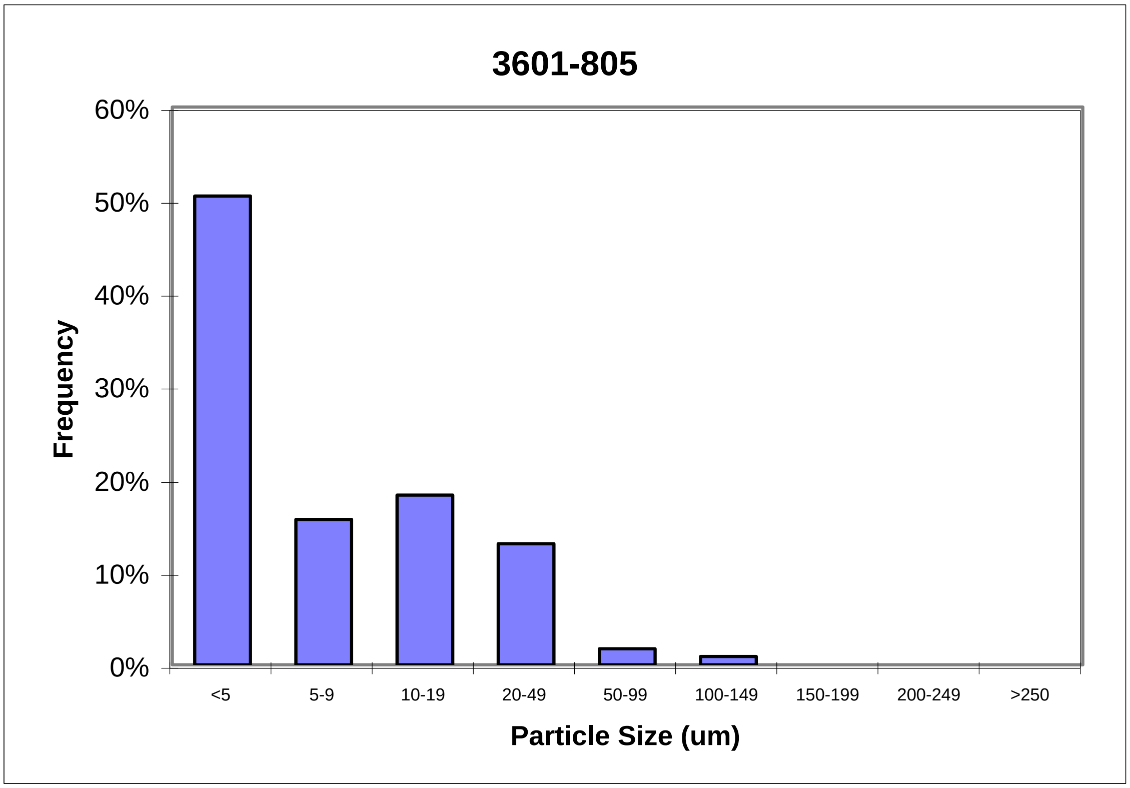
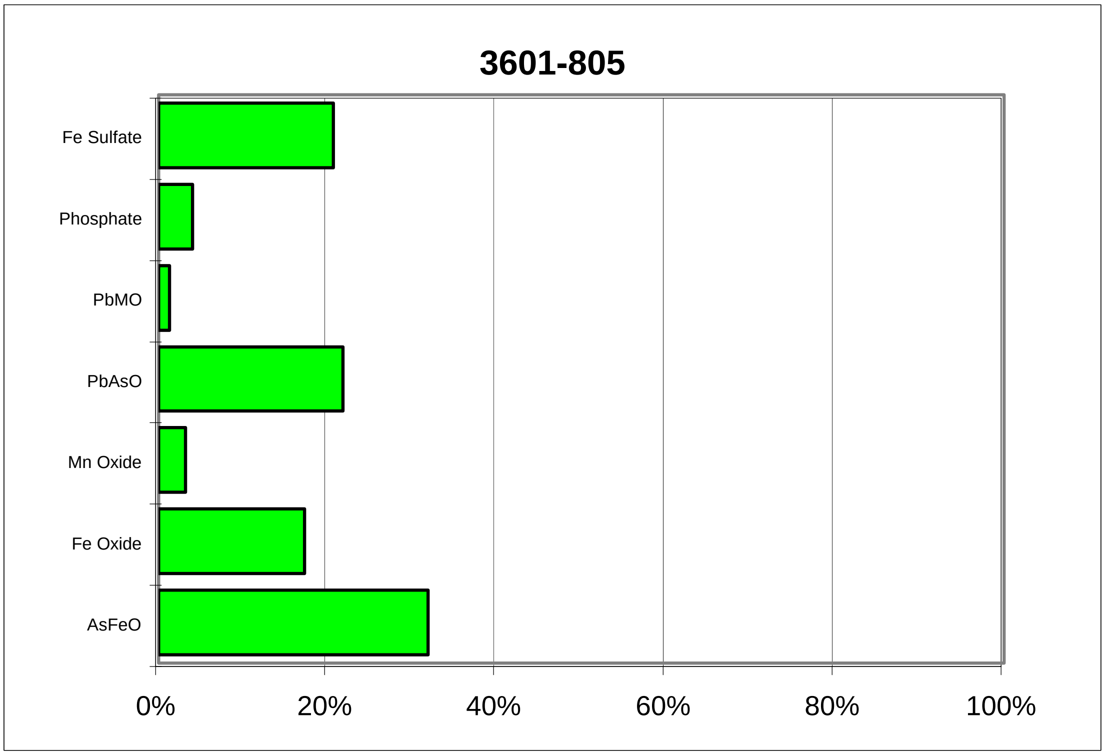


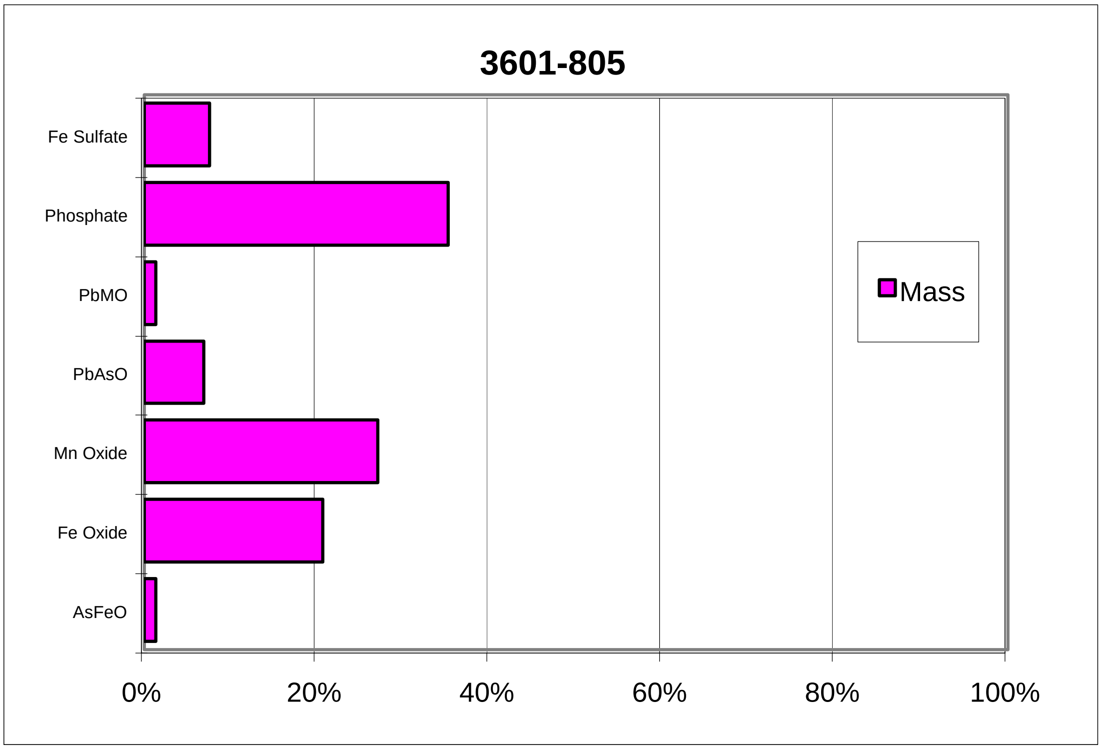
FIGURE 1 PARTICLE SIZE DISTRIBUTION



RELATIVE ARSENIC MASS



RELATIVE LEAD MASS



Summary

	ND-98-114 - As		ND-98-114 - Pb	
Mineral	Freq	Mass	Freq	Mass
AsFeO	2.5%	31.87%	2.5%	1.3%
Fe Oxide	53.0%	17.24%	53.0%	20.7%
Mn Oxide	25.6%	3.17%	25.6%	27.1%
PbAsO	1.1%	21.79%	1.1%	6.9%
PbMO	0.3%	1.26%	0.3%	1.3%
Phosphate	10.4%	4.03%	10.4%	35.1%
Fe Sulfate	7.0%	20.64%	7.0%	7.6%

Size	ND-98-114 - As	ND-98-114 - Pb
<5	50.4%	50.4%
5-9	15.7%	15.7%
10-19	18.3%	18.3%
20-49	13.0%	13.0%
50-99	1.7%	1.7%
100-149	0.9%	0.9%
150-199	0.0%	0.0%
200-249	0.0%	0.0%
$\geq$250	0.0%	0.0%

SUMMARY STATISTICS
3656-559 - Arsenic

	COUNTS			SIZE		Count Freq (%)		LW Freq (%)				Relative Arsenic Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract As	Total	Liberated
Clay	1	1	3	3	3	0.5%	0.5%	0.08%	0.08%	3.1	0.0005	0.0%	0.0%
AsFeO	2	2	31	12	50	0.9%	0.9%	1.72%	1.72%	4.5	0.16	9.9%	9.9%
Cerussite	18	18	18	3	40	8.5%	8.5%	8.91%	8.91%	6.6	0	0.0%	0.0%
Fe Oxide	58	58	35	1	130	27.5%	27.5%	56.52%	56.52%	4	0.0064	11.5%	11.5%
Mn Oxide	2	2	67	24	110	0.9%	0.9%	3.71%	3.71%	5	0.0014	0.2%	0.2%
Organic	3	3	58	35	80	1.4%	1.4%	4.84%	4.84%	1.3	0.0002	0.0%	0.0%
PbAsO	44	44	6	1	75	20.9%	20.9%	7.50%	7.50%	7.1	0.16	68.0%	68.0%
Phosphate	63	63	6	1	75	29.9%	29.9%	10.27%	10.27%	5	0.0044	1.8%	1.8%
Fe Sulfate	20	20	12	2	52	9.5%	9.5%	6.45%	6.45%	3.7	0.045	8.6%	8.6%
TOTAL	211	211	17			100.0%	100.0%	100.00%	100.00%			100.0%	100.0%

DISTRIBUTION				
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	57.3%	57.3%	11.7%	11.7%
5-9	7.6%	7.6%	4.3%	4.3%
10-19	5.2%	5.2%	5.3%	5.3%
20-49	18.0%	18.0%	40.6%	40.6%
50-99	9.5%	9.5%	35.2%	35.2%
100-149	2.4%	2.4%	3.0%	3.0%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	100%	100%	100%

SUMMARY STATISTICS
3656-559 - Lead

	COUNTS		SIZE			Count Freq (%)		LW Freq (%)				Relative Lead Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract Pb	Total	Liberated
Clay	1	1	3	3	3	0.5%	0.5%	0.08%	0.08%	3.1	0.005	0.0%	0.0%
AsFeO	2	2	31	12	50	0.9%	0.9%	1.72%	1.72%	4.5	0.073	0.5%	0.5%
Cerussite	18	18	18	3	40	8.5%	8.5%	8.91%	8.91%	6.6	0.77	38.8%	38.8%
Fe Oxide	58	58	35	1	130	27.5%	27.5%	56.52%	56.52%	4	0.06	11.6%	11.6%
Mn Oxide	2	2	67	24	110	0.9%	0.9%	3.71%	3.71%	5	0.13	2.1%	2.1%
Organic	3	3	58	35	80	1.4%	1.4%	4.84%	4.84%	1.3	0.023	0.0%	0.0%
PbAsO	44	44	6	1	75	20.9%	20.9%	7.50%	7.50%	7.1	0.55	25.1%	25.1%
Phosphate	63	63	6	1	75	29.9%	29.9%	10.27%	10.27%	5	0.418	18.4%	18.4%
Fe Sulfate	20	20	12	2	52	9.5%	9.5%	6.45%	6.45%	3.7	0.18	3.7%	3.7%
TOTAL	211	211	17			100.0%	100.0%	100.00%	100.00%			100.0%	100.0%

DISTRIBUTION				
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	57.3%	57.3%	9.2%	9.2%
5-9	7.6%	7.6%	7.6%	7.6%
10-19	5.2%	5.2%	7.9%	7.9%
20-49	18.0%	18.0%	52.7%	52.7%
50-99	9.5%	9.5%	18.1%	18.1%
100-149	2.4%	2.4%	4.5%	4.5%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	100%	100%	100%

MINERAL FREQUENCY OBSERVED IN SITE SOIL

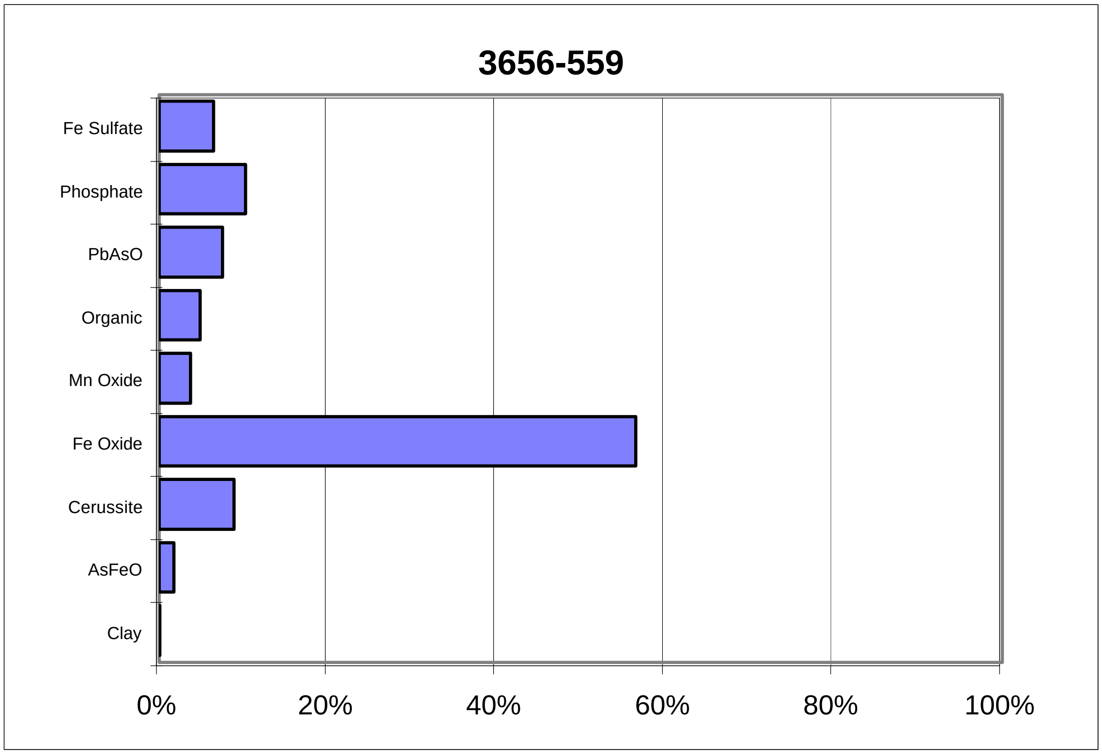
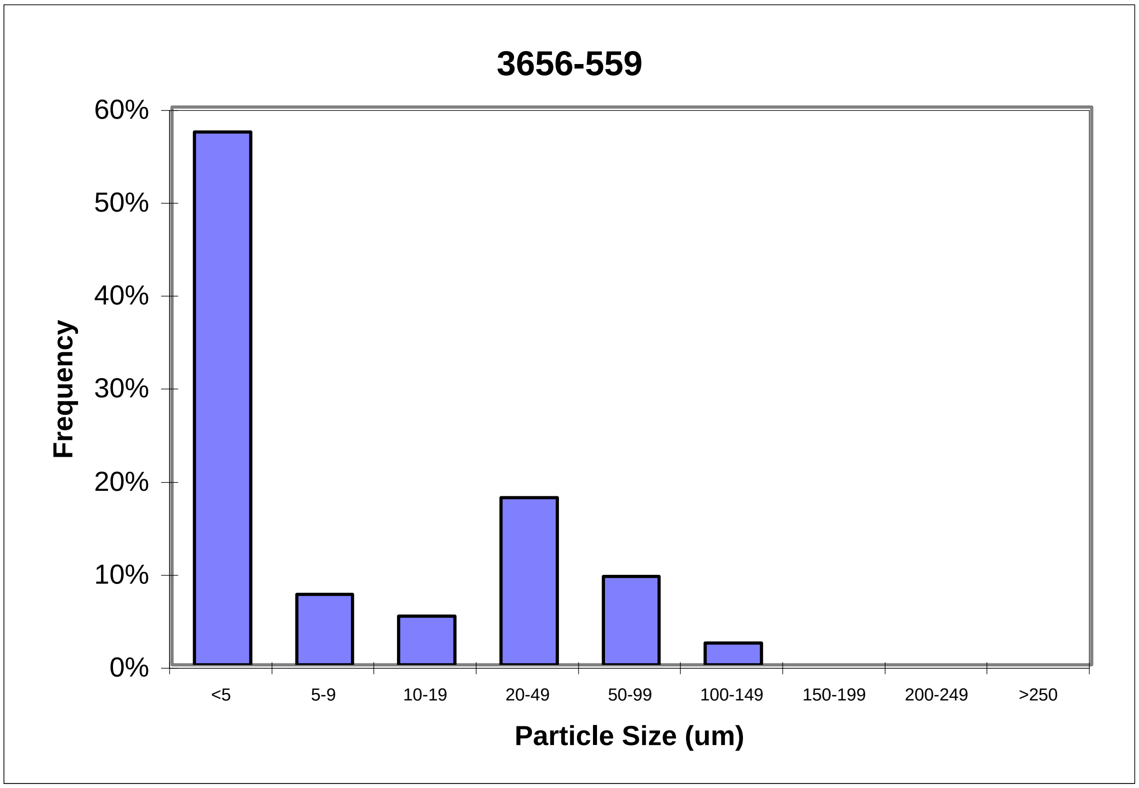
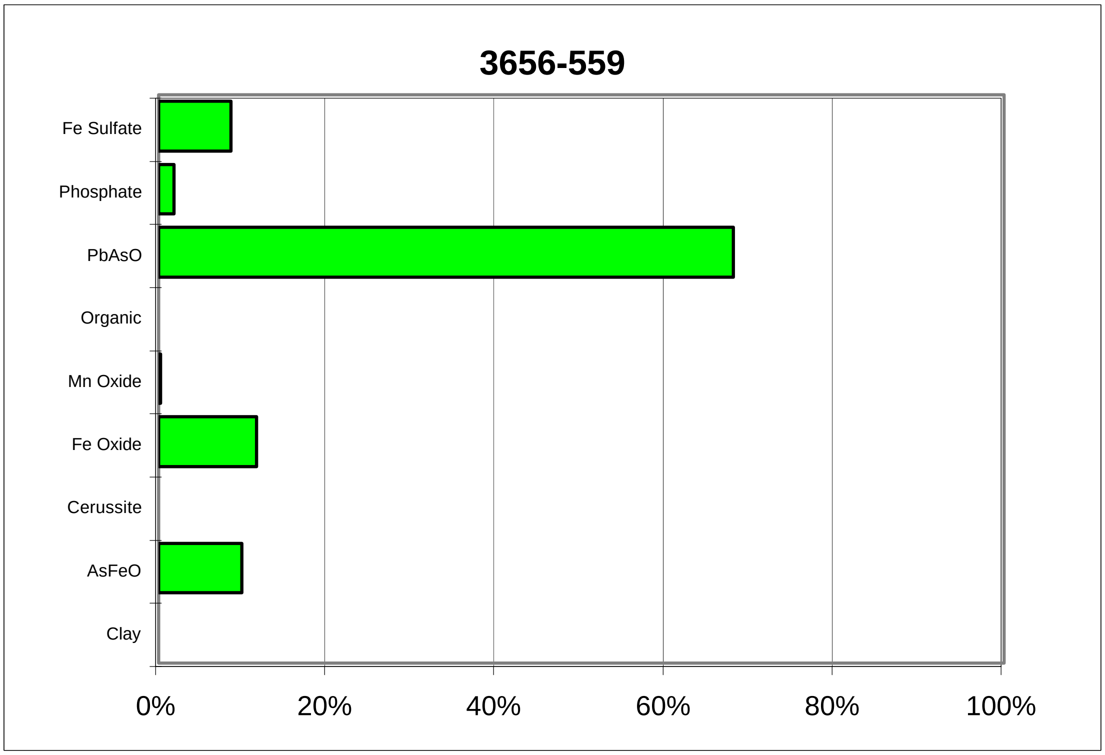


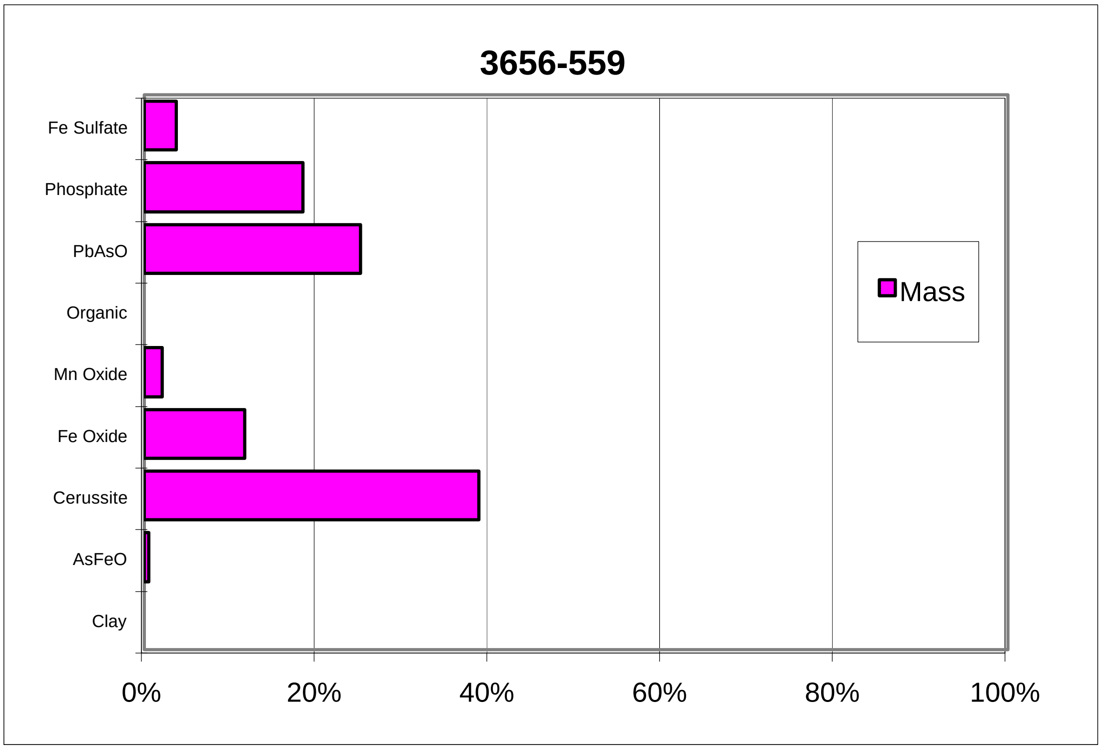
FIGURE 1 PARTICLE SIZE DISTRIBUTION



RELATIVE ARSENIC MASS



RELATIVE LEAD MASS



Summary

Mineral	3656-559 - As Freq	3656-559 - As Mass	3656-559 - Pb Freq	3656-559 - Pb Mass
Clay	0.1%	0.00%	0.1%	0.0%
AsFeO	1.7%	9.86%	1.7%	0.5%
Cerussite	8.9%	0.00%	8.9%	38.8%
Fe Oxide	56.5%	11.55%	56.5%	11.6%
Mn Oxide	3.7%	0.21%	3.7%	2.1%
Organic	4.8%	0.00%	4.8%	0.0%
PbAsO	7.5%	68.01%	7.5%	25.1%
Phosphate	10.3%	1.80%	10.3%	18.4%
Fe Sulfate	6.4%	8.57%	6.4%	3.7%

Size	3656-559 - As	3656-559 - Pb
<5	57.3%	57.3%
5-9	7.6%	7.6%
10-19	5.2%	5.2%
20-49	18.0%	18.0%
50-99	9.5%	9.5%
100-149	2.4%	2.4%
150-199	0.0%	0.0%
200-249	0.0%	0.0%
≥250	0.0%	0.0%

SUMMARY STATISTICS
ND-360-442 - Arsenic

	COUNTS			SIZE		Count Freq (%)		LW Freq (%)				Relative Arsenic Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract As	Total	Liberated
Anglesite	1	1	15	15	15	0.8%	0.8%	1.15%	1.15%	6.3	0	0.0%	0.0%
Barite	1	1	3	3	3	0.8%	0.8%	0.23%	0.23%	4	0	0.0%	0.0%
Fe Oxide	64	64	14	1	85	52.0%	52.0%	68.68%	68.68%	4	0.0064	60.9%	60.9%
Mn Oxide	21	21	9	2	30	17.1%	17.1%	15.16%	15.16%	5	0.0014	3.7%	3.7%
PbMO	1	1	3	3	3	0.8%	0.8%	0.23%	0.23%	7.1	0.03	1.7%	1.7%
Phosphate	29	29	5	1	55	23.6%	23.6%	10.03%	10.03%	5	0.0044	7.6%	7.6%
Fe Sulfate	6	6	10	1	42	4.9%	4.9%	4.52%	4.52%	3.7	0.045	26.1%	26.1%
TOTAL	123	123	11			100.0%	100.0%	100.00%	100.00%			100.0%	100.0%

	DISTRIBUTION			
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	53.7%	53.7%	12.5%	12.5%
5-9	16.3%	16.3%	12.1%	12.1%
10-19	13.8%	13.8%	11.8%	11.8%
20-49	12.2%	12.2%	40.4%	40.4%
50-99	4.1%	4.1%	23.2%	23.2%
100-149	0.0%	0.0%	0.0%	0.0%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	100%	100%	100%

SUMMARY STATISTICS
3660-442 - Lead

	COUNTS		SIZE			Count Freq (%)		LW Freq (%)				Relative Lead Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract Pb	Total	Liberated
Anglesite	1	1	15	15	15	0.8%	0.8%	1.15%	1.15%	6.3	0.684	8.9%	8.9%
Barite	1	1	3	3	3	0.8%	0.8%	0.23%	0.23%	4	0.057	0.1%	0.1%
Fe Oxide	64	64	14	1	85	52.0%	52.0%	68.68%	68.68%	4	0.06	29.5%	29.5%
Mn Oxide	21	21	9	2	30	17.1%	17.1%	15.16%	15.16%	5	0.13	17.6%	17.6%
PbMO	1	1	3	3	3	0.8%	0.8%	0.23%	0.23%	7.1	0.34	1.0%	1.0%
Phosphate	29	29	5	1	55	23.6%	23.6%	10.03%	10.03%	5	0.418	37.5%	37.5%
Fe Sulfate	6	6	10	1	42	4.9%	4.9%	4.52%	4.52%	3.7	0.18	5.4%	5.4%
TOTAL	123	123	11			100.0%	100.0%	100.00%	100.00%			100.0%	100.0%

	DISTRIBUTION			
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	53.7%	53.7%	20.5%	20.5%
5-9	16.3%	16.3%	7.0%	7.0%
10-19	13.8%	13.8%	18.7%	18.7%
20-49	12.2%	12.2%	28.4%	28.4%
50-99	4.1%	4.1%	25.5%	25.5%
100-149	0.0%	0.0%	0.0%	0.0%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	100%	100%	100%

MINERAL FREQUENCY OBSERVED IN SITE SOIL

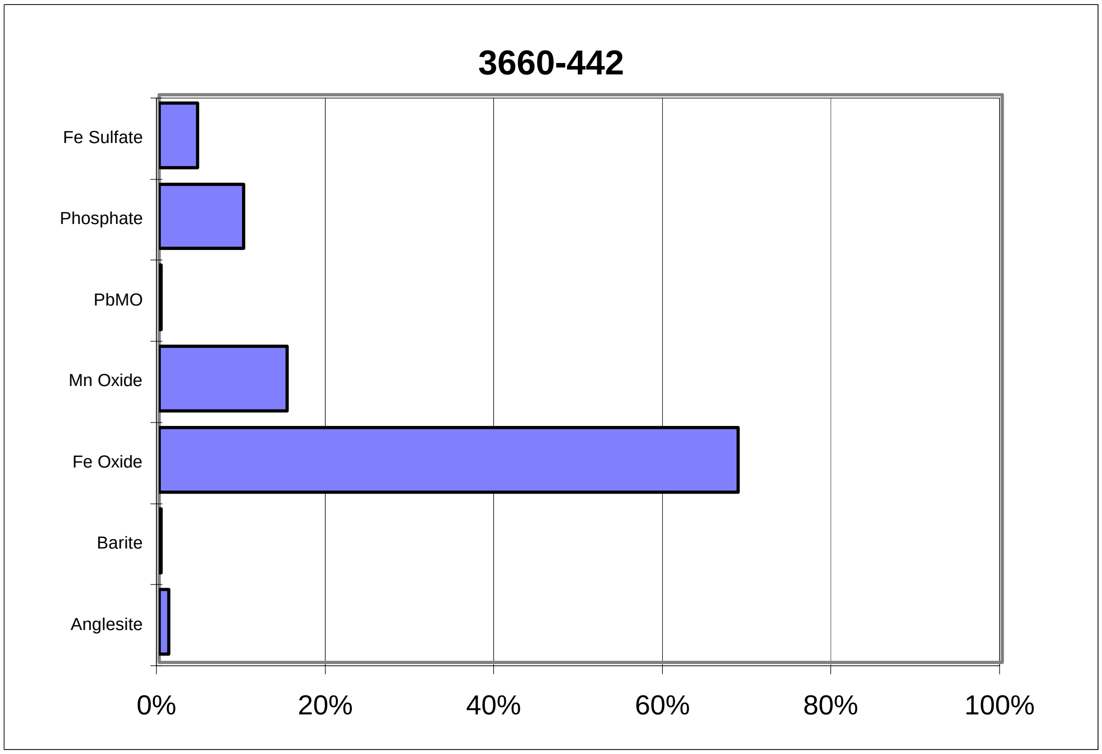
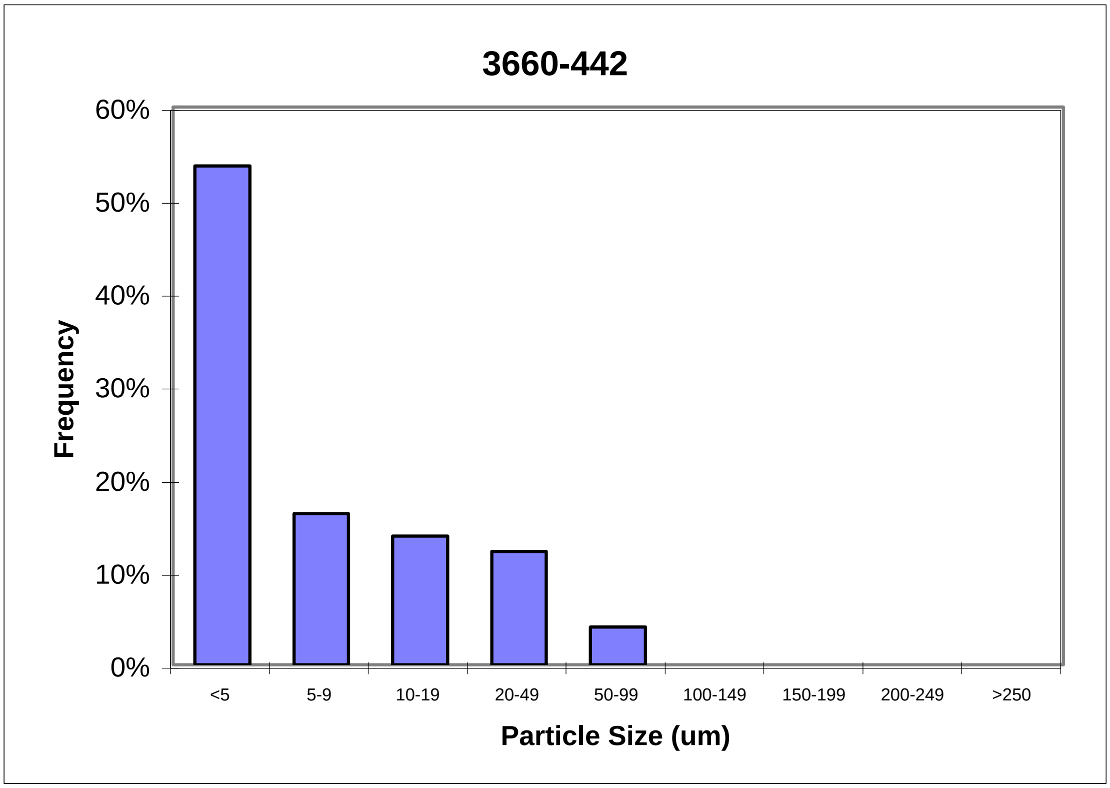
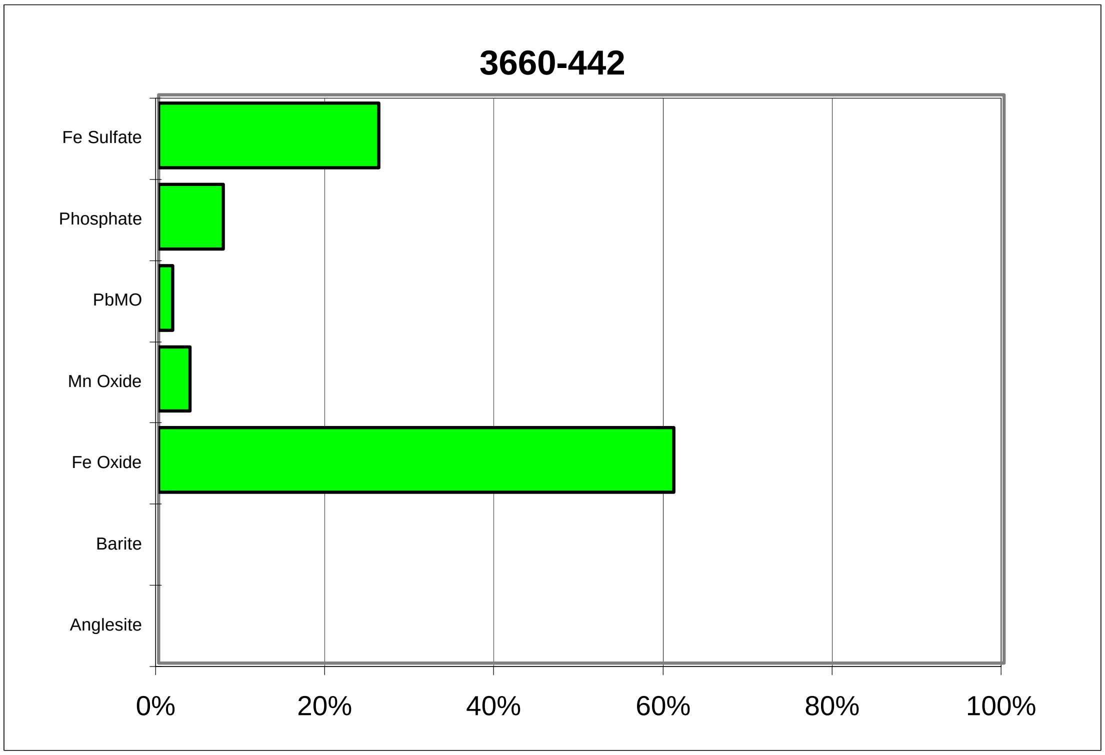


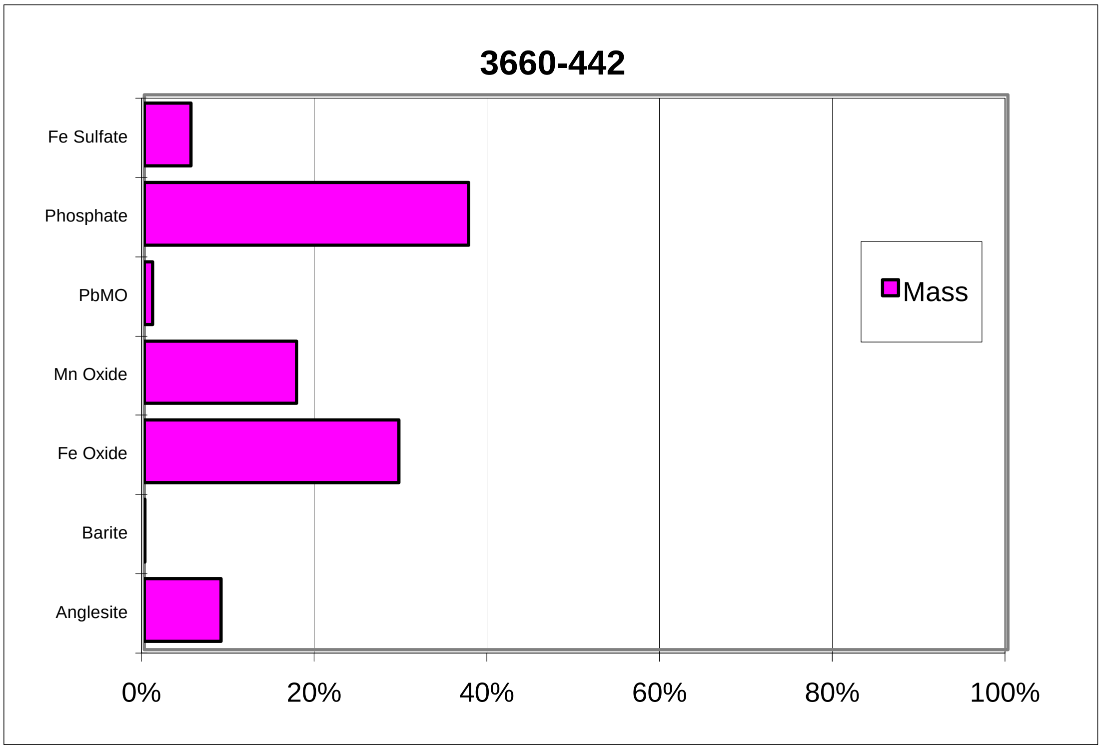
FIGURE 1 PARTICLE SIZE DISTRIBUTION



RELATIVE ARSENIC MASS



RELATIVE LEAD MASS



Summary

	3660-442 - As		3660-442 - Pb	
Mineral	Freq	Mass	Freq	Mass
Anglesite	1.1%	0.00%	1.1%	8.9%
Barite	0.2%	0.00%	0.2%	0.1%
Fe Oxide	68.7%	60.92%	68.7%	29.5%
Mn Oxide	15.2%	3.68%	15.2%	17.6%
PbMO	0.2%	1.70%	0.2%	1.0%
Phosphate	10.0%	7.65%	10.0%	37.5%
Fe Sulfate	4.5%	26.06%	4.5%	5.4%

Size	3660-442 - As	3660-442 - Pb
<5	53.7%	53.7%
5-9	16.3%	16.3%
10-19	13.8%	13.8%
20-49	12.2%	12.2%
50-99	4.1%	4.1%
100-149	0.0%	0.0%
150-199	0.0%	0.0%
200-249	0.0%	0.0%
≥250	0.0%	0.0%

SUMMARY STATISTICS
9600-668 - Arsenic

	COUNTS		SIZE			Count Freq (%)		LW Freq (%)				Relative Arsenic Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract As	Total	Liberated
Fe Oxide	50	50	7	1	32	64.1%	64.1%	56.91%	56.91%	4	0.0064	20.3%	20.3%
Galena	1	1	2	2	2	1.3%	1.3%	0.33%	0.33%	7.5	0	0.0%	0.0%
Mn Oxide	9	9	18	6	40	11.5%	11.5%	26.79%	26.79%	5	0.0014	2.6%	2.6%
PbAsO	4	4	5	1	9	5.1%	5.1%	3.00%	3.00%	7.1	0.16	47.3%	47.3%
PbMO	7	7	3	1	7	9.0%	9.0%	3.83%	3.83%	7.1	0.03	11.3%	11.3%
Phosphate	1	1	8	8	8	1.3%	1.3%	1.33%	1.33%	5	0.0044	0.4%	0.4%
Fe Sulfate	6	6	8	2	15	7.7%	7.7%	7.82%	7.82%	3.7	0.045	18.1%	18.1%
TOTAL	78	78	8			100.0%	100.0%	100.00%	100.00%			100.0%	100.0%

	DISTRIBUTION			
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	35.9%	35.9%	21.0%	21.0%
5-9	42.3%	42.3%	54.4%	54.4%
10-19	15.4%	15.4%	21.1%	21.1%
20-49	6.4%	6.4%	3.5%	3.5%
50-99	0.0%	0.0%	0.0%	0.0%
100-149	0.0%	0.0%	0.0%	0.0%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	100%	100%	100%

SUMMARY STATISTICS
9600-668 - Arsenic

	COUNTS			SIZE		Count Freq (%)		LW Freq (%)				Relative Lead Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract Pb	Total	Liberated
Fe Oxide	50	50	7	1	32	64.1%	64.1%	56.91%	56.91%	4	0.06	22.0%	22.0%
Galena	1	1	2	2	2	1.3%	1.3%	0.33%	0.33%	7.5	0.886	3.6%	3.6%
Mn Oxide	9	9	18	6	40	11.5%	11.5%	26.79%	26.79%	5	0.13	28.0%	28.0%
PbAsO	4	4	5	1	9	5.1%	5.1%	3.00%	3.00%	7.1	0.55	18.8%	18.8%
PbMO	7	7	3	1	7	9.0%	9.0%	3.83%	3.83%	7.1	0.34	14.9%	14.9%
Phosphate	1	1	8	8	8	1.3%	1.3%	1.33%	1.33%	5	0.418	4.5%	4.5%
Fe Sulfate	6	6	8	2	15	7.7%	7.7%	7.82%	7.82%	3.7	0.18	8.4%	8.4%
TOTAL	78	78	8			100.0%	100.0%	100.00%	100.00%			100.0%	100.0%

	DISTRIBUTION			
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	35.9%	35.9%	18.6%	18.6%
5-9	42.3%	42.3%	41.5%	41.5%
10-19	15.4%	15.4%	20.5%	20.5%
20-49	6.4%	6.4%	19.4%	19.4%
50-99	0.0%	0.0%	0.0%	0.0%
100-149	0.0%	0.0%	0.0%	0.0%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	100%	100%	100%

MINERAL FREQUENCY OBSERVED IN SITE SOIL

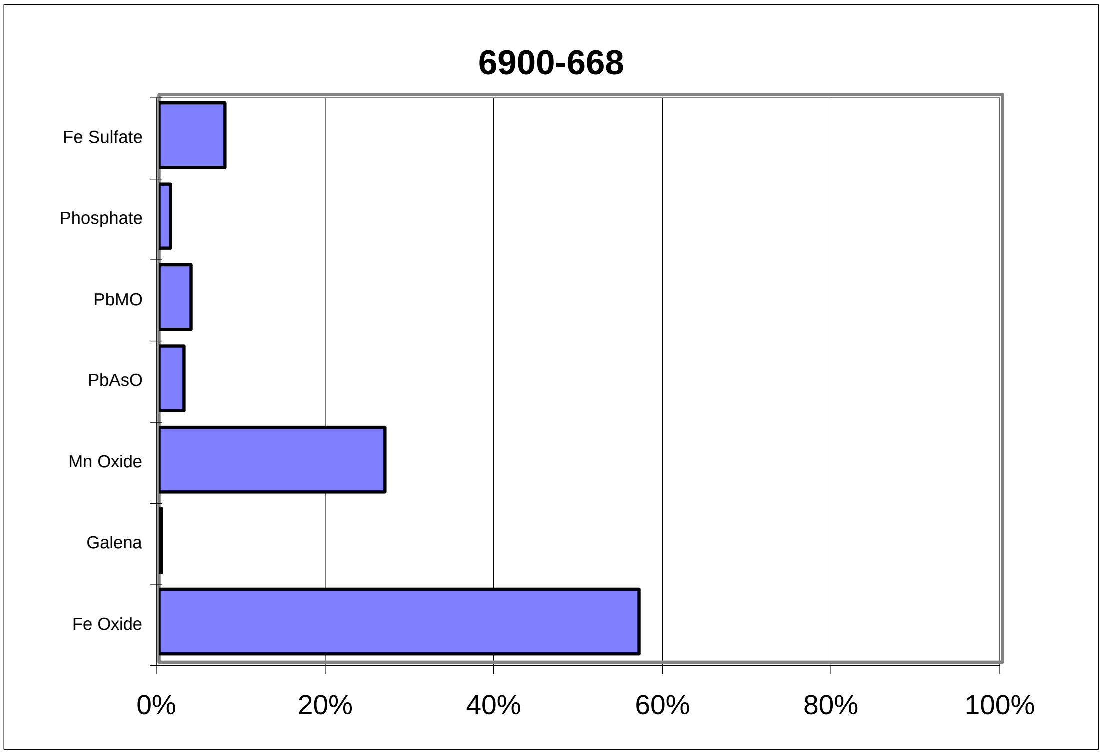
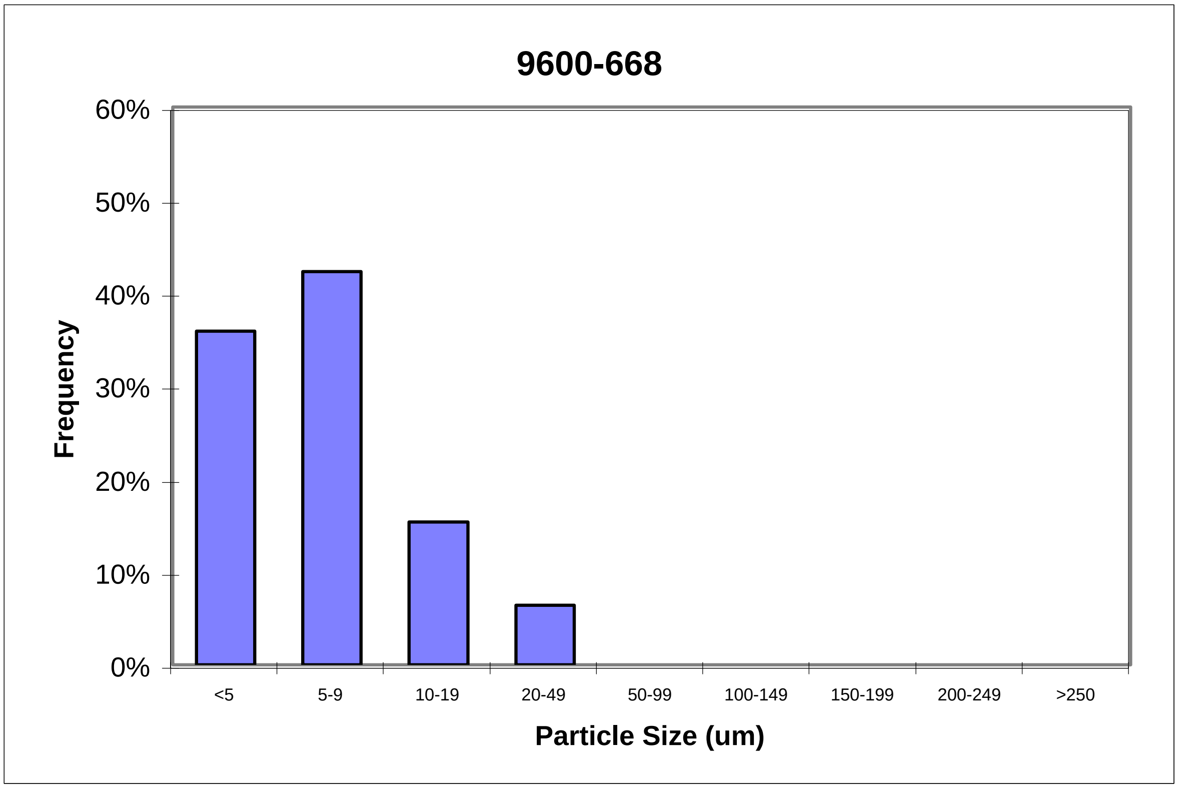
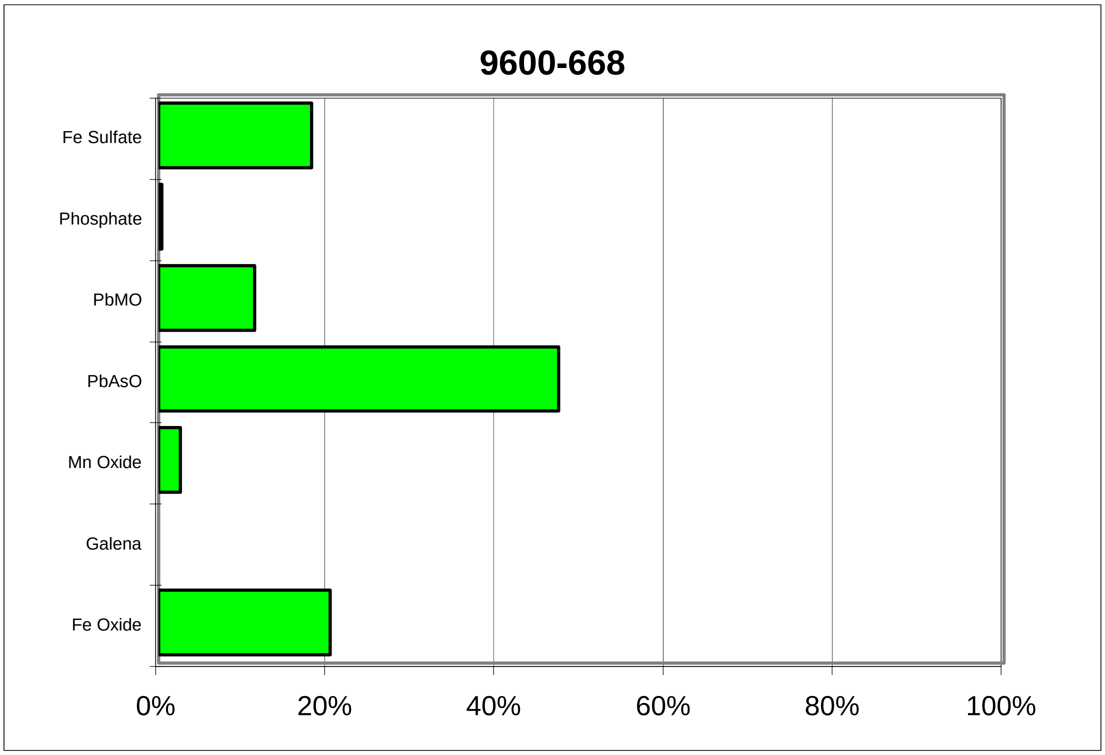


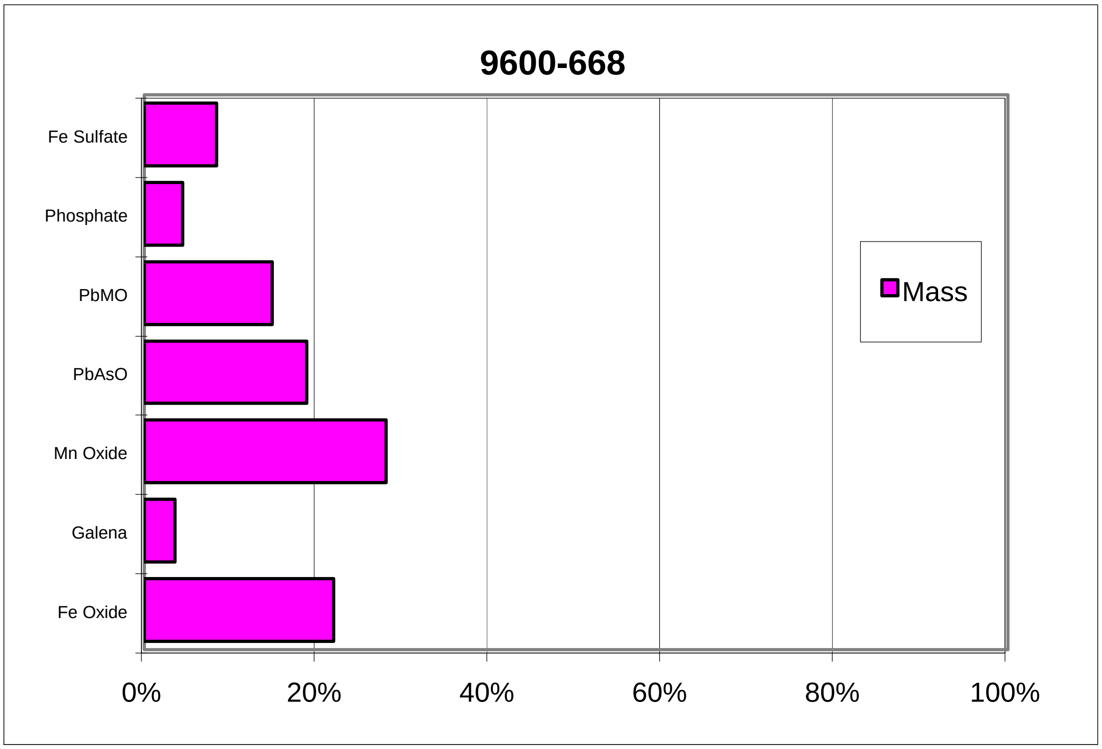
FIGURE 1 PARTICLE SIZE DISTRIBUTION



RELATIVE ARSENIC MASS



RELATIVE LEAD MASS



Summary

	9600-668 - As		9600-668 - Pb	
Mineral	Freq	Mass	Freq	Mass
Fe Oxide	56.9%	20.25%	56.9%	22.0%
Galena	0.3%	0.00%	0.3%	3.6%
Mn Oxide	26.8%	2.61%	26.8%	28.0%
PbAsO	3.0%	47.30%	3.0%	18.8%
PbMO	3.8%	11.33%	3.8%	14.9%
Phosphate	1.3%	0.41%	1.3%	4.5%
Fe Sulfate	7.8%	18.10%	7.8%	8.4%

Size	9600-668 - As	9600-668 - Pb
<5	35.9%	35.9%
5-9	42.3%	42.3%
10-19	15.4%	15.4%
20-49	6.4%	6.4%
50-99	0.0%	0.0%
100-149	0.0%	0.0%
150-199	0.0%	0.0%
200-249	0.0%	0.0%
≥250	0.0%	0.0%

SUMMARY STATISTICS
9650-610 - Arsenic

	COUNTS		SIZE			Count Freq (%)		LW Freq (%)				Relative Arsenic Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract As	Total	Liberated
Enargite	1	1	3	3	3	1.3%	1.3%	0.53%	0.53%	6	0.18	10.4%	10.4%
Fe Oxide	57	57	7	2	50	76.0%	76.0%	68.61%	68.61%	4	0.0064	31.9%	31.9%
Mn Oxide	12	12	8	2	15	16.0%	16.0%	17.11%	17.11%	5	0.0014	2.2%	2.2%
PbAsO	1	1	15	15	15	1.3%	1.3%	2.65%	2.65%	7.1	0.16	54.6%	54.6%
PbSiO4	1	1	50	50	50	1.3%	1.3%	8.82%	8.82%	6	0	0.0%	0.0%
Phosphate	3	3	4	1	11	4.0%	4.0%	2.29%	2.29%	5	0.0044	0.9%	0.9%
TOTAL	75	75	8			100.0%	100.0%	100.00%	100.00%			100.0%	100.0%

	DISTRIBUTION			
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	44.0%	44.0%	16.2%	16.2%
5-9	29.3%	29.3%	9.9%	9.9%
10-19	20.0%	20.0%	62.9%	62.9%
20-49	4.0%	4.0%	7.0%	7.0%
50-99	2.7%	2.7%	4.1%	4.1%
100-149	0.0%	0.0%	0.0%	0.0%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	100%	100%	100%

SUMMARY STATISTICS
9650-610 - Arsenic

Mineral	COUNTS Total	Lib	Avg	SIZE Min	Max	Count Freq (%) Total	Liberated	LW Freq (%) Total	Liberated	Density	Fract Pb	Relative Lead Mass (%) Total	Liberated
Enargite	1	1	3	3	3	1.3%	1.3%	0.53%	0.53%	6	0.25	1.1%	1.1%
Fe Oxide	57	57	7	2	50	76.0%	76.0%	68.61%	68.61%	4	0.06	23.5%	23.5%
Mn Oxide	12	12	8	2	15	16.0%	16.0%	17.11%	17.11%	5	0.13	15.9%	15.9%
PbAsO	1	1	15	15	15	1.3%	1.3%	2.65%	2.65%	7.1	0.55	14.8%	14.8%
PbSiO4	1	1	50	50	50	1.3%	1.3%	8.82%	8.82%	6	0.5	37.8%	37.8%
Phosphate	3	3	4	1	11	4.0%	4.0%	2.29%	2.29%	5	0.418	6.8%	6.8%

DISTRIBUTION Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	44.0%	44.0%	7.2%	7.2%
5-9	29.3%	29.3%	10.4%	10.4%
10-19	20.0%	20.0%	36.4%	36.4%
20-49	4.0%	4.0%	5.1%	5.1%
50-99	2.7%	2.7%	40.8%	40.8%
100-149	0.0%	0.0%	0.0%	0.0%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	100%	100%	100%

MINERAL FREQUENCY OBSERVED IN SITE SOIL

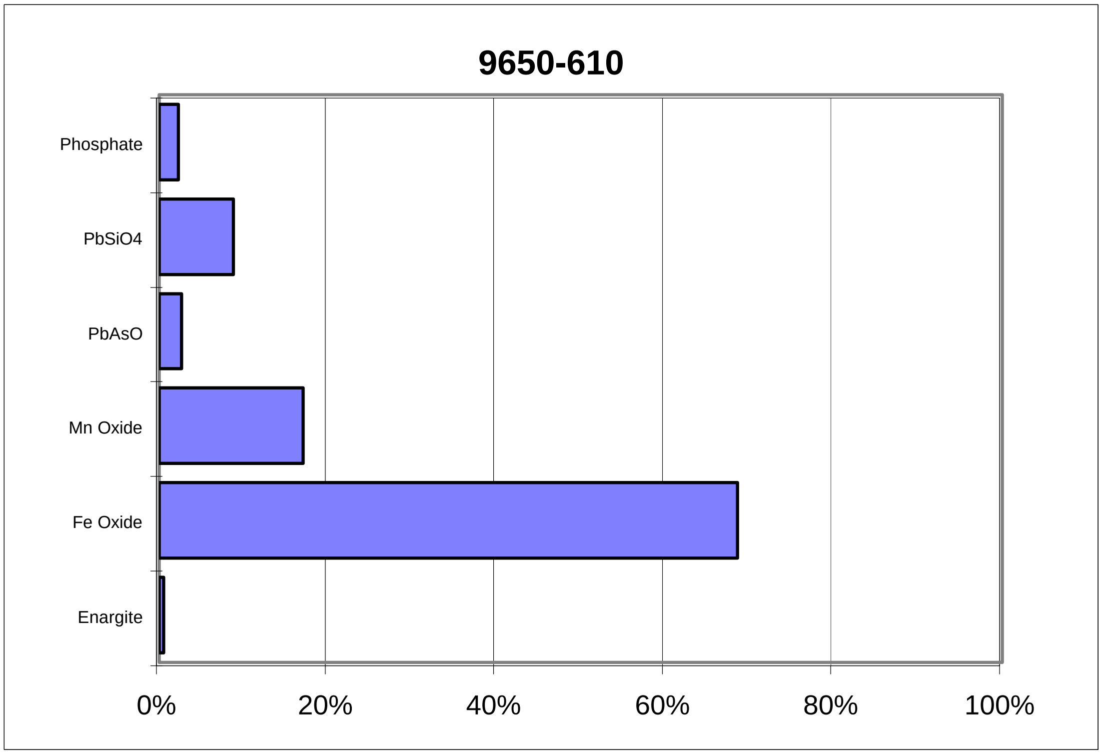
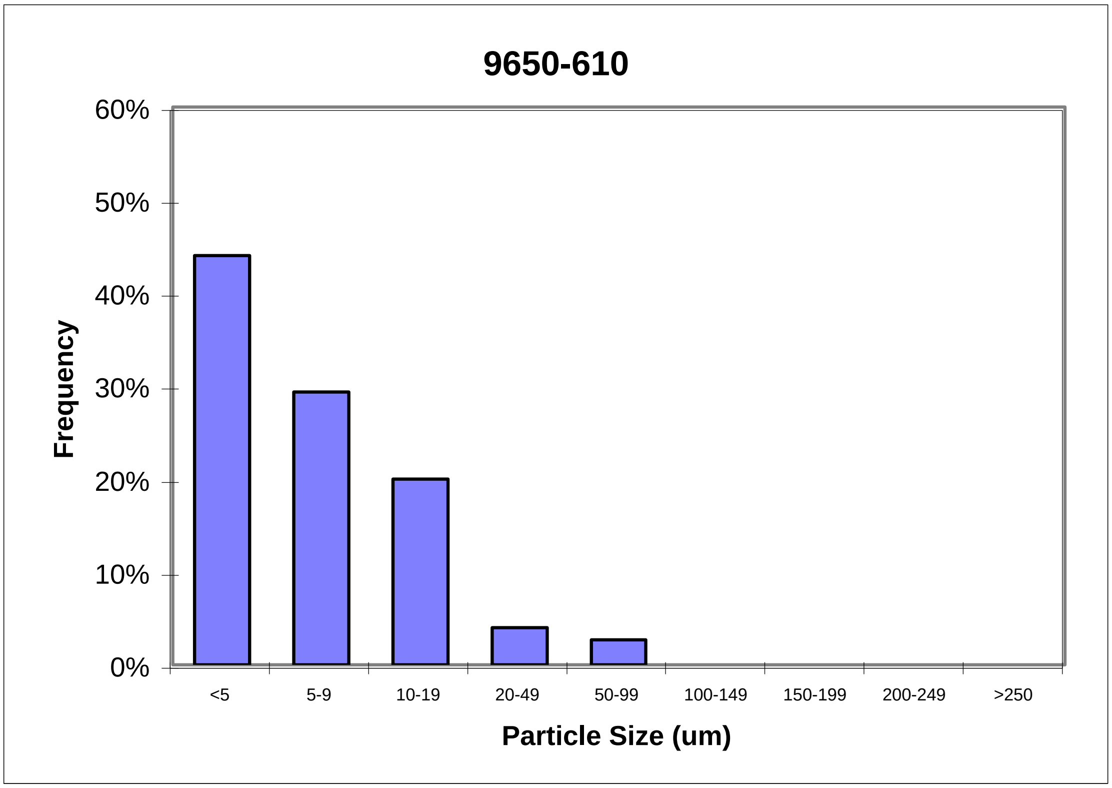
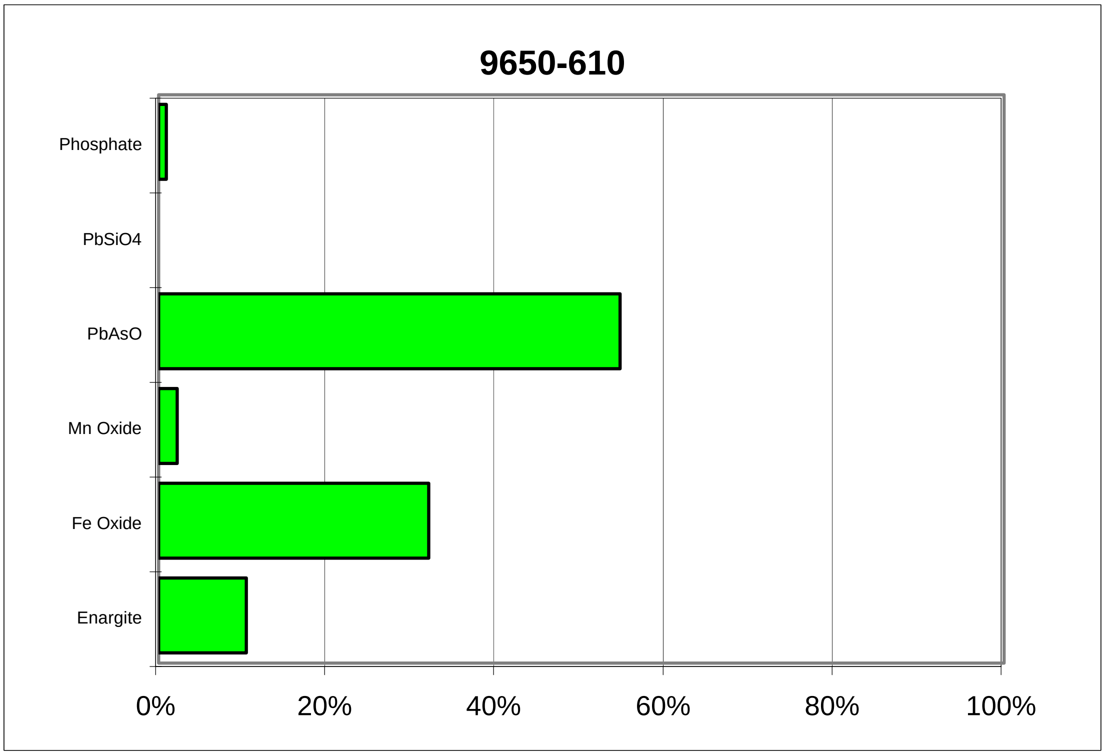


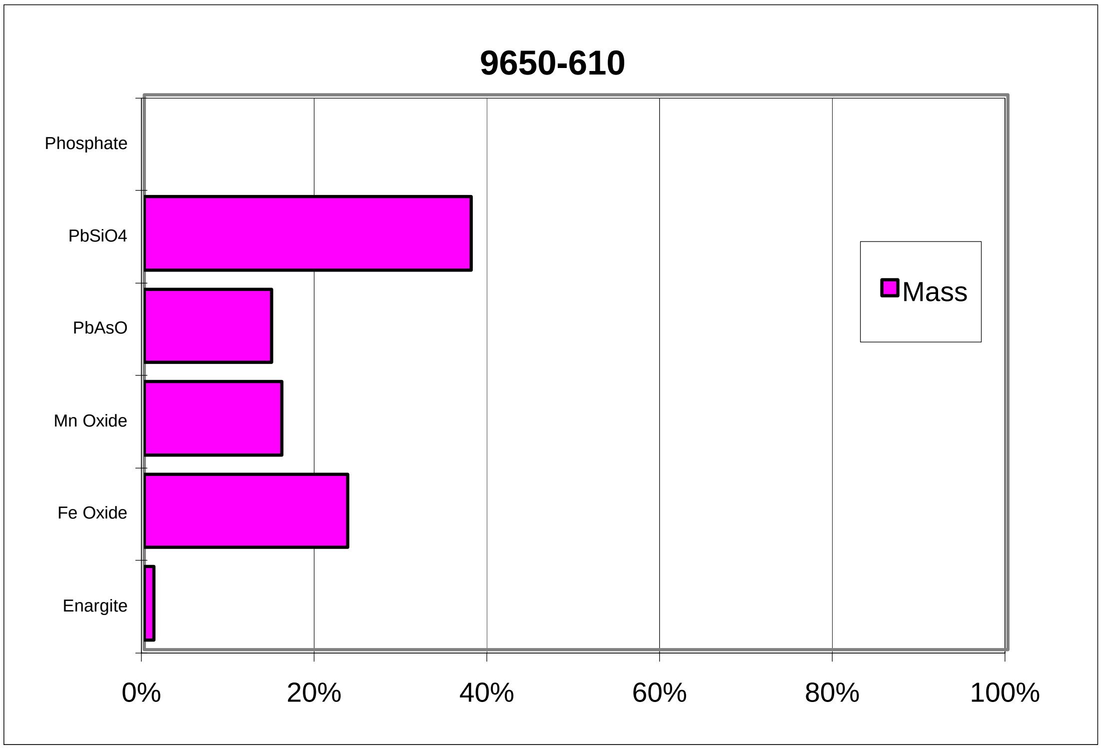
FIGURE 1 PARTICLE SIZE DISTRIBUTION



RELATIVE ARSENIC MASS



RELATIVE LEAD MASS



	9650-610 - As		9650-610 - Pb	
Mineral	Freq	Mass	Freq	Mass
Enargite	0.5%	10.38%	0.5%	1.1%
Fe Oxide	68.6%	31.91%	68.6%	23.5%
Mn Oxide	17.1%	2.18%	17.1%	15.9%
PbAsO	2.6%	54.61%	2.6%	14.8%
PbSiO4	8.8%	0.00%	8.8%	37.8%
Phosphate	2.3%	0.92%	0.0%	0.0%

Size	9650-610 - As	9650-610 - Pb
<5	44.0%	44.0%
5-9	29.3%	29.3%
10-19	20.0%	20.0%
20-49	4.0%	4.0%
50-99	2.7%	2.7%
100-149	0.0%	0.0%
150-199	0.0%	0.0%
200-249	0.0%	0.0%
≥250	0.0%	0.0%

SUMMARY STATISTICS
9682-217 - Arsenic

	COUNTS		SIZE			Count Freq (%)		LW Freq (%)				Relative Arsenic Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract As	Total	Liberated
Fe Oxide	51	51	8	1	35	51.0%	51.0%	71.22%	71.22%	4	0.0064	63.4%	63.4%
Mn Oxide	29	29	4	1	12	29.0%	29.0%	18.53%	18.53%	5	0.0014	4.5%	4.5%
PbMO	1	1	12	12	12	1.0%	1.0%	2.16%	2.16%	7.1	0.03	16.0%	16.0%
Phosphate	13	13	3	1	12	13.0%	13.0%	6.12%	6.12%	5	0.0044	4.7%	4.7%
Fe Sulfate	6	6	2	1	2	6.0%	6.0%	1.98%	1.98%	3.7	0.045	11.5%	11.5%
TOTAL	100	100	6			100.0%	100.0%	100.00%	100.00%			100.0%	100.0%

	DISTRIBUTION			
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	66.0%	66.0%	22.7%	22.7%
5-9	16.0%	16.0%	14.5%	14.5%
10-19	11.0%	11.0%	34.0%	34.0%
20-49	7.0%	7.0%	28.8%	28.8%
50-99	0.0%	0.0%	0.0%	0.0%
100-149	0.0%	0.0%	0.0%	0.0%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	100%	100%	100%

SUMMARY STATISTICS
9682-217-Lead

	COUNTS		SIZE			Count Freq (%)		LW Freq (%)				Relative Lead Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract Pb	Total	Liberated
Fe Oxide	51	51	8	1	35	51.0%	51.0%	71.22%	71.22%	4	0.06	35.3%	35.3%
Mn Oxide	29	29	4	1	12	29.0%	29.0%	18.53%	18.53%	5	0.13	24.9%	24.9%
PbMO	1	1	12	12	12	1.0%	1.0%	2.16%	2.16%	7.1	0.34	10.8%	10.8%
Phosphate	13	13	3	1	12	13.0%	13.0%	6.12%	6.12%	5	0.418	26.4%	26.4%
Fe Sulfate	6	6	2	1	2	6.0%	6.0%	1.98%	1.98%	3.7	0.18	2.7%	2.7%

	DISTRIBUTION			
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	66.0%	66.0%	35.0%	35.0%
5-9	16.0%	16.0%	17.2%	17.2%
10-19	11.0%	11.0%	31.8%	31.8%
20-49	7.0%	7.0%	16.0%	16.0%
50-99	0.0%	0.0%	0.0%	0.0%
100-149	0.0%	0.0%	0.0%	0.0%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	100%	100%	100%

MINERAL FREQUENCY OBSERVED IN SITE SOIL

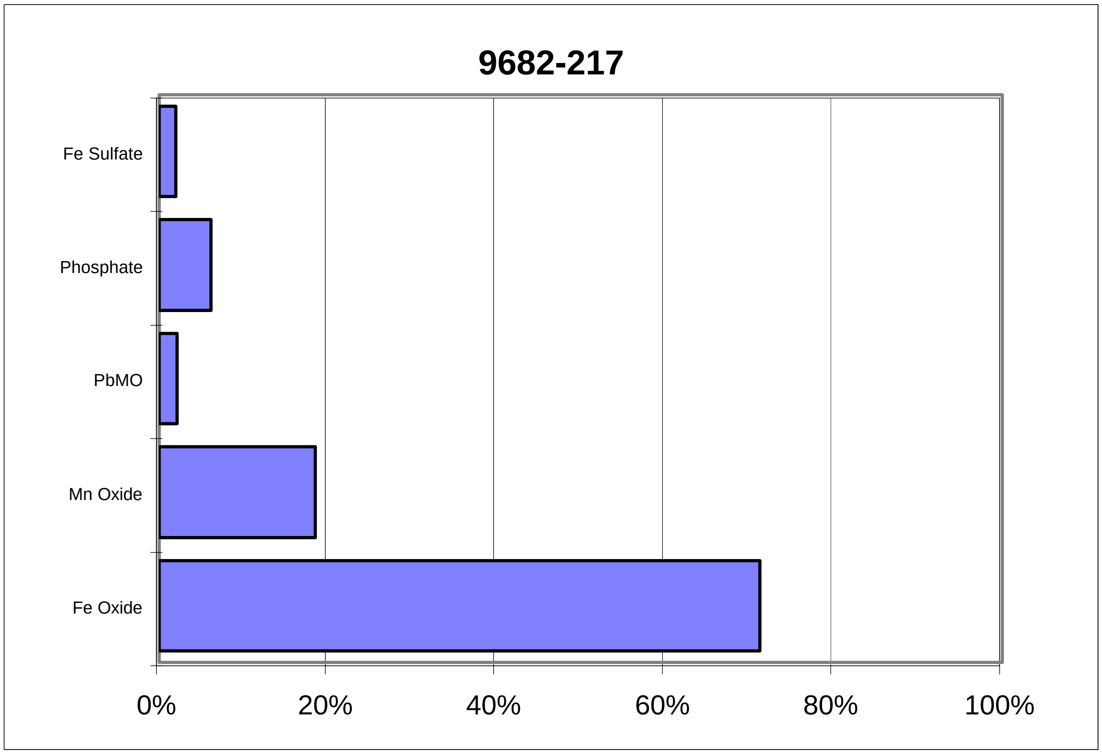
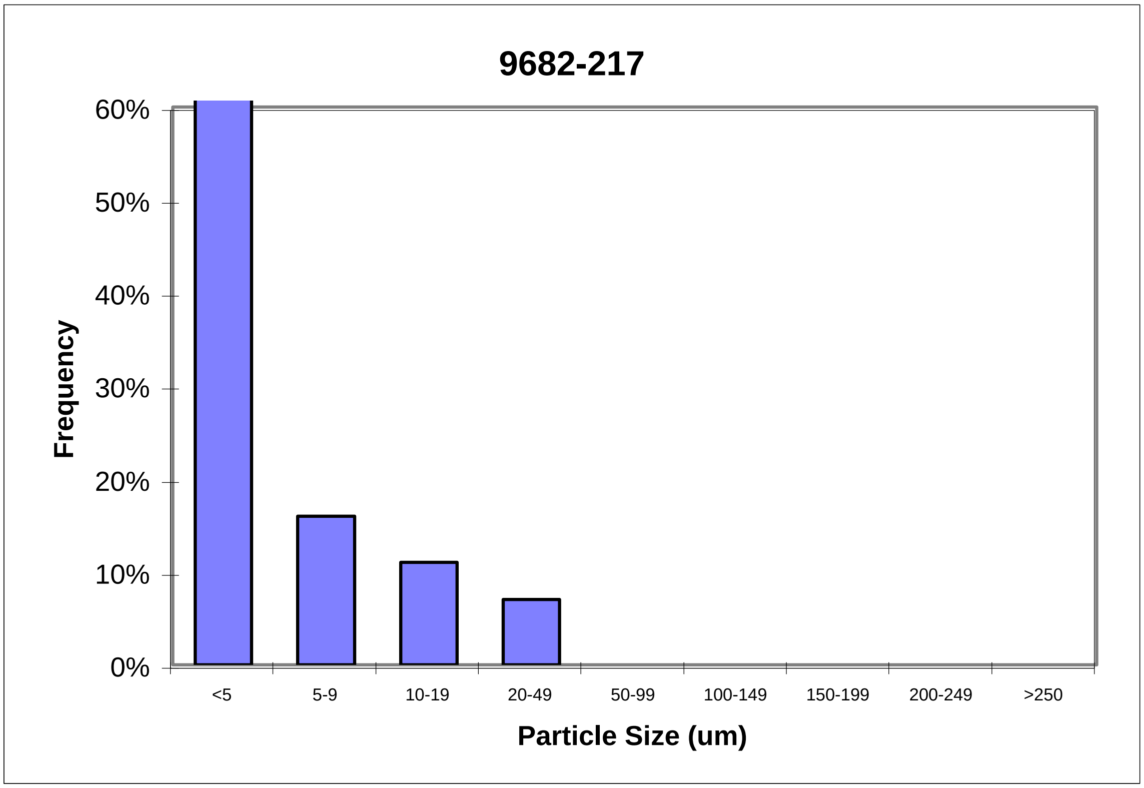
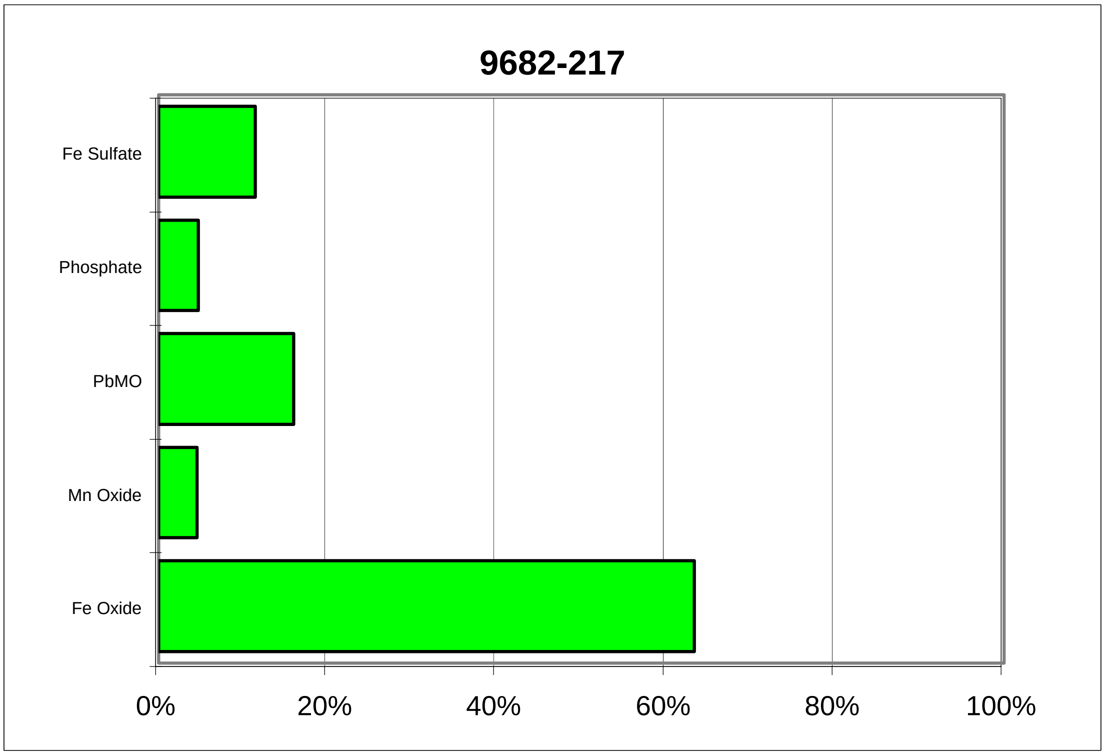


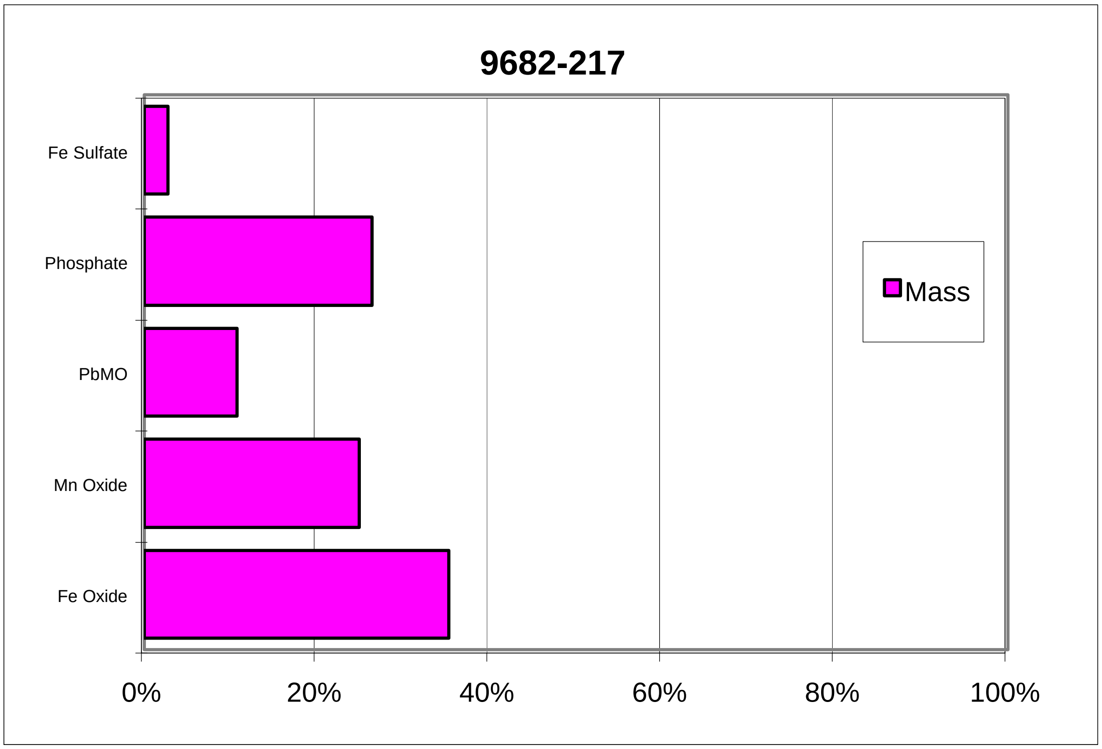
FIGURE 1 PARTICLE SIZE DISTRIBUTION



RELATIVE ARSENIC MASS



RELATIVE LEAD MASS



	9682-217 - As		9682-217 - Pb	
Mineral	Freq	Mass	Freq	Mass
Fe Oxide	71.2%	63.38%	71.2%	35.3%
Mn Oxide	18.5%	4.51%	18.5%	24.9%
PbMO	2.2%	15.98%	2.2%	10.8%
Phosphate	6.1%	4.68%	6.1%	26.4%
Fe Sulfate	2.0%	11.45%	2.0%	2.7%

Size	9682-217 - As	9682-217 - Pb
<5	66.0%	66.0%
5-9	16.0%	16.0%
10-19	11.0%	11.0%
20-49	7.0%	7.0%
50-99	0.0%	0.0%
100-149	0.0%	0.0%
150-199	0.0%	0.0%
200-249	0.0%	0.0%
≥250	0.0%	0.0%

SUMMARY STATISTICS
9712-233 - Arsenic

	COUNTS		SIZE			Count Freq (%)		LW Freq (%)				Relative Arsenic Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract As	Total	Liberated
Pb Barite	1	1	8	8	8	0.8%	0.8%	0.51%	0.51%	4	0	0.0%	0.0%
Fe Oxide	50	50	17	2	100	38.5%	38.5%	53.26%	53.26%	4	0.0064	27.7%	27.7%
Mn Oxide	25	25	14	3	65	19.2%	19.2%	21.72%	21.72%	5	0.0014	3.1%	3.1%
PbAsO	2	2	7	2	11	1.5%	1.5%	0.82%	0.82%	7.1	0.16	19.0%	19.0%
PbMO	6	6	7	1	12	4.6%	4.6%	2.66%	2.66%	7.1	0.03	11.5%	11.5%
Phosphate	34	34	5	1	27	26.2%	26.2%	11.02%	11.02%	5	0.0044	4.9%	4.9%
Fe Sulfate	12	12	13	1	60	9.2%	9.2%	10.01%	10.01%	3.7	0.045	33.8%	33.8%
TOTAL	130	130	12			100.0%	100.0%	100.00%	100.00%			100.0%	100.0%

	DISTRIBUTION			
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	42.3%	42.3%	10.1%	10.1%
5-9	27.7%	27.7%	13.9%	13.9%
10-19	13.8%	13.8%	31.6%	31.6%
20-49	10.0%	10.0%	18.9%	18.9%
50-99	5.4%	5.4%	22.2%	22.2%
100-149	0.8%	0.8%	3.3%	3.3%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	100%	100%	100%

SUMMARY STATISTICS
9712-233 - Arsenic

	COUNTS		SIZE			Count Freq (%)		LW Freq (%)				Relative Lead Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract Pb	Total	Liberated
Pb Barite	1	1	8	8	8	0.8%	0.8%	0.51%	0.51%	4	0.057	0.2%	0.2%
Fe Oxide	50	50	17	2	100	38.5%	38.5%	53.26%	53.26%	4	0.06	19.3%	19.3%
Mn Oxide	25	25	14	3	65	19.2%	19.2%	21.72%	21.72%	5	0.13	21.3%	21.3%
PbAsO	2	2	7	2	11	1.5%	1.5%	0.82%	0.82%	7.1	0.55	4.8%	4.8%
PbMO	6	0	7	1	12	4.6%	0.0%	2.66%	0.00%	7.1	0.34	9.7%	0.0%
Phosphate	34	0	5	1	27	26.2%	0.0%	11.02%	0.00%	5	0.418	34.7%	0.0%
Fe Sulfate	12	0	13	1	60	9.2%	0.0%	10.01%	0.00%	3.7	0.18	10.0%	0.0%

	DISTRIBUTION			
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	42.3%	19.2%	16.4%	4.3%
5-9	27.7%	18.5%	22.4%	5.4%
10-19	13.8%	8.5%	20.9%	7.6%
20-49	10.0%	8.5%	20.8%	12.6%
50-99	5.4%	4.6%	17.2%	13.4%
100-149	0.8%	0.8%	2.3%	2.3%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	60%	100%	46%

MINERAL FREQUENCY OBSERVED IN SITE SOIL

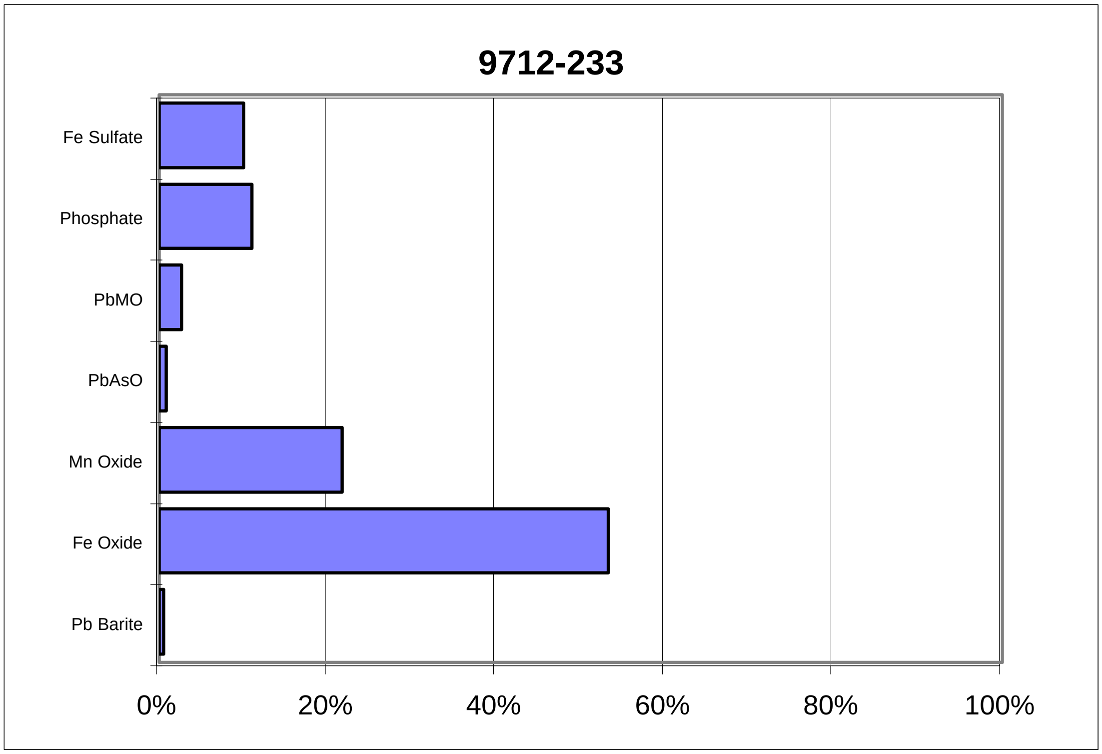
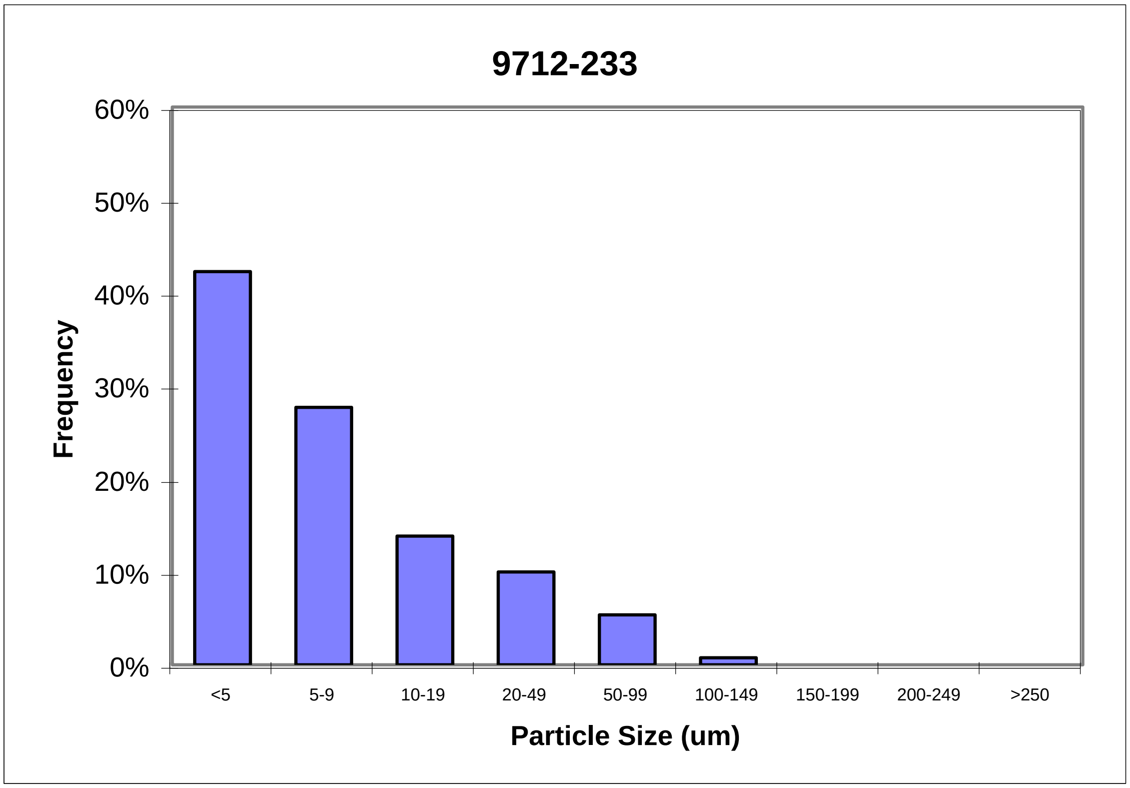
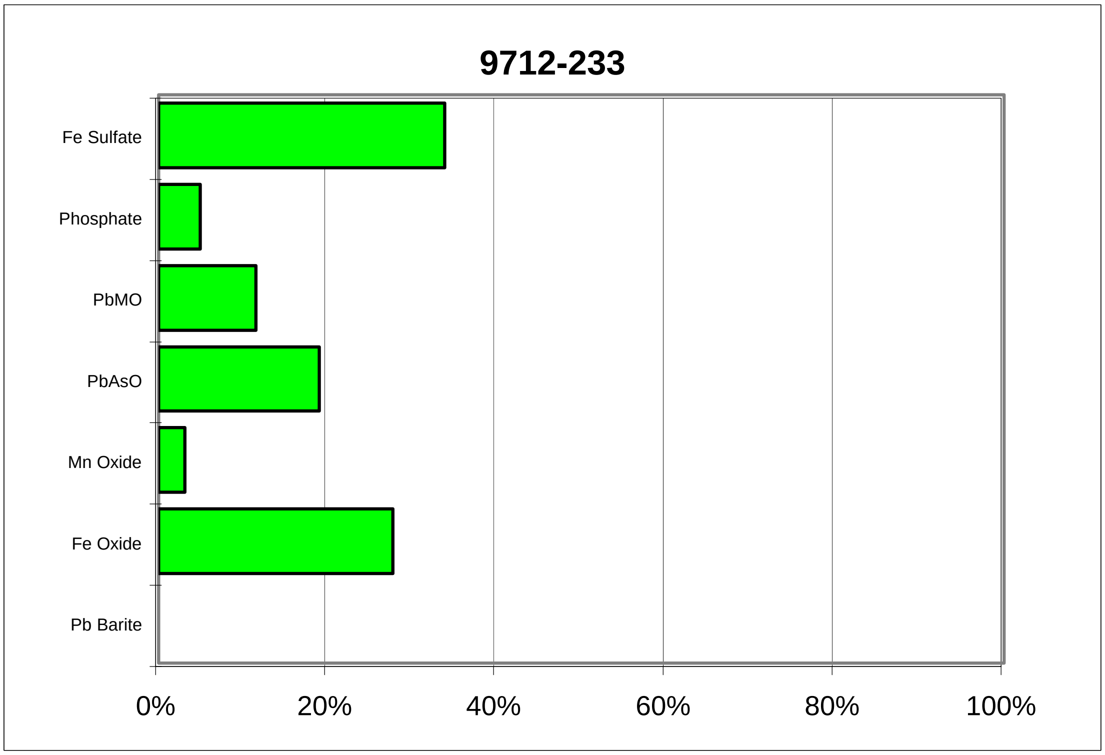


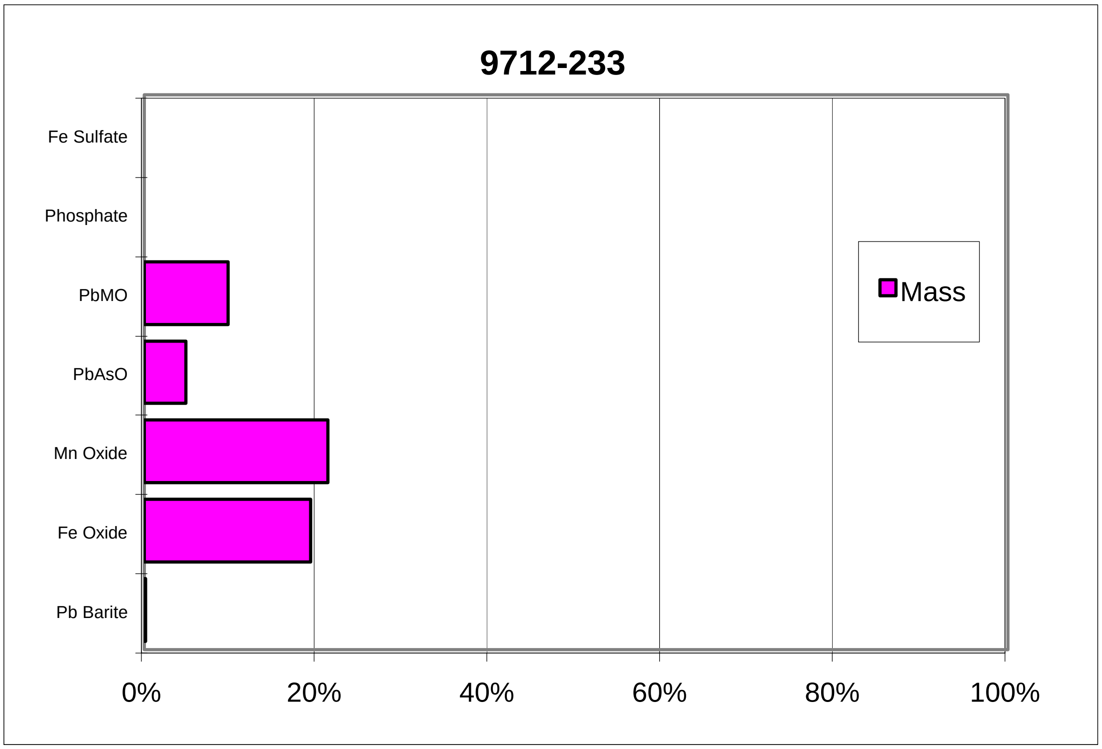
FIGURE 1 PARTICLE SIZE DISTRIBUTION



RELATIVE ARSENIC MASS



RELATIVE LEAD MASS



	9712-233 - As		9712-2338 - Pb	
Mineral	Freq	Mass	Freq	Mass
Pb Barite	0.5%	0.00%	0.5%	0.2%
Fe Oxide	53.3%	27.68%	53.3%	19.3%
Mn Oxide	21.7%	3.09%	21.7%	21.3%
PbAsO	0.8%	18.99%	0.8%	4.8%
PbMO	2.7%	11.50%	2.7%	9.7%
Phosphate	11.0%	4.92%	0.0%	0.0%
Fe Sulfate	10.0%	33.82%	0.0%	0.0%

Size	9712-233 - As	9712-233 - Pb
<5	42.3%	42.3%
5-9	27.7%	27.7%
10-19	13.8%	13.8%
20-49	10.0%	10.0%
50-99	5.4%	5.4%
100-149	0.8%	0.8%
150-199	0.0%	0.0%
200-249	0.0%	0.0%
$\geq$250	0.0%	0.0%

SUMMARY STATISTICS
ND-9756-157 - Arsenic

	COUNTS			SIZE		Count Freq (%)		LW Freq (%)				Relative Arsenic Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract As	Total	Liberated
Anglesite	17	17	28	1	125	14.8%	14.8%	17.03%	17.03%	6.3	0	0.0%	0.0%
Pb Barite	3	3	3	2	4	2.6%	2.6%	0.32%	0.32%	4	0	0.0%	0.0%
Cerussite	1	1	3	3	3	0.9%	0.9%	0.11%	0.11%	6.6	0	0.0%	0.0%
Fe Oxide	51	51	23	1	112	44.3%	44.3%	41.31%	41.31%	4	0.0064	17.1%	17.1%
Mn Oxide	9	9	33	8	75	7.8%	7.8%	10.51%	10.51%	5	0.0014	1.2%	1.2%
PbAsO	5	5	6	1	20	4.3%	4.3%	1.13%	1.13%	7.1	0.16	20.9%	20.9%
PbMO	1	1	3	3	3	0.9%	0.9%	0.11%	0.11%	7.1	0.03	0.4%	0.4%
Phosphate	12	12	19	1	98	10.4%	10.4%	8.18%	8.18%	5	0.0044	2.9%	2.9%
Fe Sulfate	16	16	38	2	100	13.9%	13.9%	21.31%	21.31%	3.7	0.045	57.5%	57.5%
TOTAL	115	115	25			100.0%	100.0%	100.00%	100.00%			100.0%	100.0%

DISTRIBUTION				
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	37.4%	37.4%	5.8%	5.8%
5-9	10.4%	10.4%	5.8%	5.8%
10-19	16.5%	16.5%	7.4%	7.4%
20-49	17.4%	17.4%	35.4%	35.4%
50-99	13.9%	13.9%	23.1%	23.1%
100-149	4.3%	4.3%	22.4%	22.4%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
$\geq$250	0.0%	0.0%	0.0%	0.0%
	100%	100%	100%	100%

SUMMARY STATISTICS
9756-157-Lead

	COUNTS			SIZE		Count Freq (%)		LW Freq (%)				Relative Lead Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract Pb	Total	Liberated
Anglesite	17	17	28	1	125	14.8%	14.8%	17.03%	17.03%	6.3	0.684	57.9%	57.9%
Pb Barite	3	3	3	2	4	2.6%	2.6%	0.32%	0.32%	4	0.057	0.1%	0.1%
Cerussite	1	1	3	3	3	0.9%	0.9%	0.11%	0.11%	6.6	0.776	0.4%	0.4%
Fe Oxide	51	51	23	1	112	44.3%	44.3%	41.31%	41.31%	4	0.06	7.8%	7.8%
Mn Oxide	9	9	33	8	75	7.8%	7.8%	10.51%	10.51%	5	0.13	5.4%	5.4%
PbAsO	5	5	6	1	20	4.3%	4.3%	1.13%	1.13%	7.1	0.55	3.5%	3.5%
PbMO	1	1	3	3	3	0.9%	0.9%	0.11%	0.11%	7.1	0.34	0.2%	0.2%
Phosphate	12	12	19	1	98	10.4%	10.4%	8.18%	8.18%	5	0.418	13.5%	13.5%
Fe Sulfate	16	16	38	2	100	13.9%	13.9%	21.31%	21.31%	3.7	0.18	11.2%	11.2%

	DISTRIBUTION			
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	37.4%	37.4%	5.0%	5.0%
5-9	10.4%	10.4%	2.9%	2.9%
10-19	16.5%	16.5%	5.6%	5.6%
20-49	17.4%	17.4%	17.4%	17.4%
50-99	13.9%	13.9%	48.9%	48.9%
100-149	4.3%	4.3%	20.3%	20.3%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	100%	100%	100%

MINERAL FREQUENCY OBSERVED IN SITE SOIL

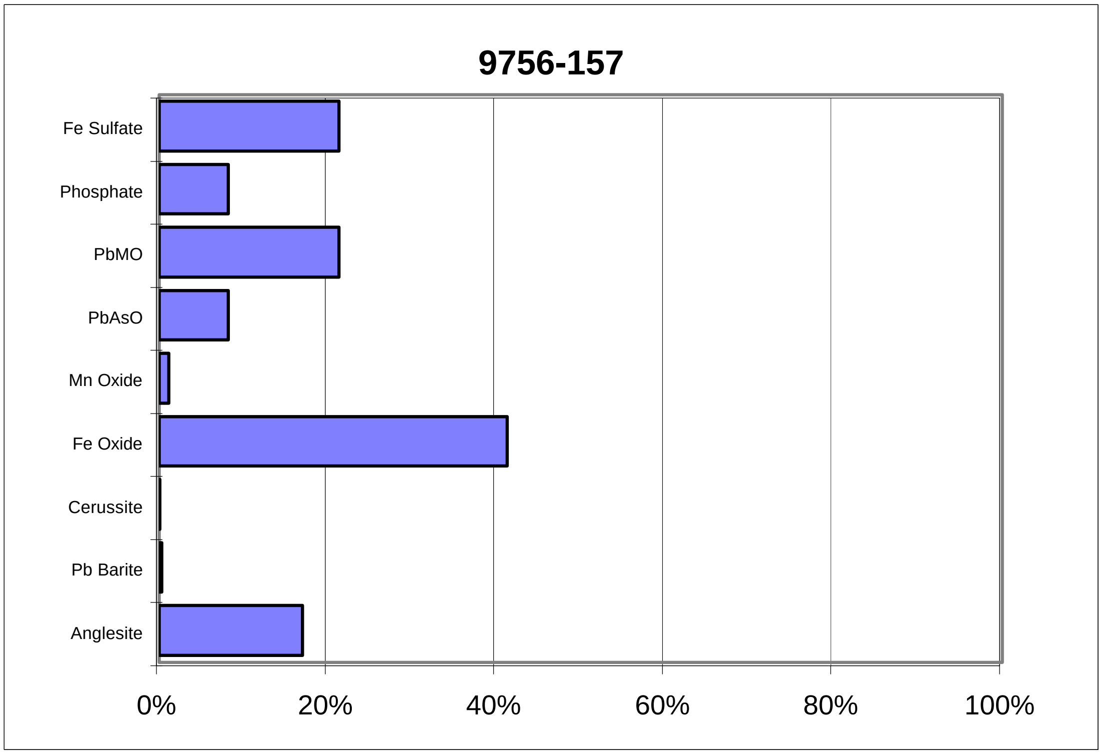
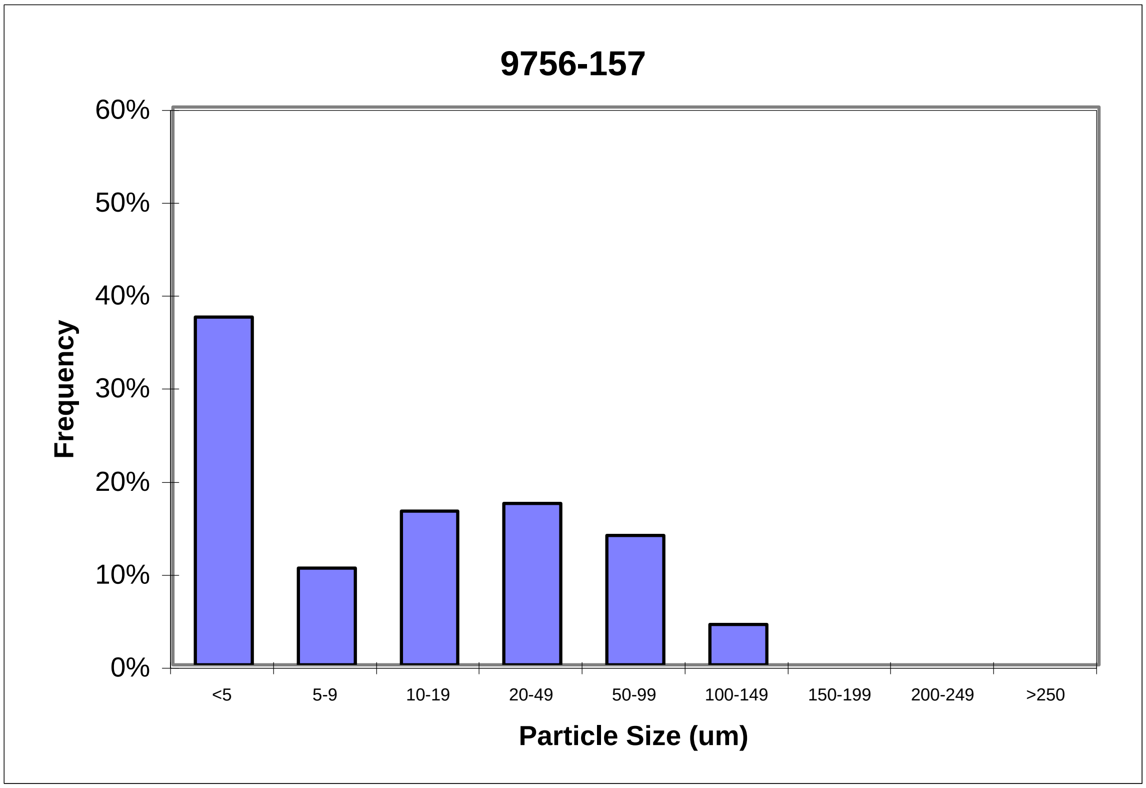
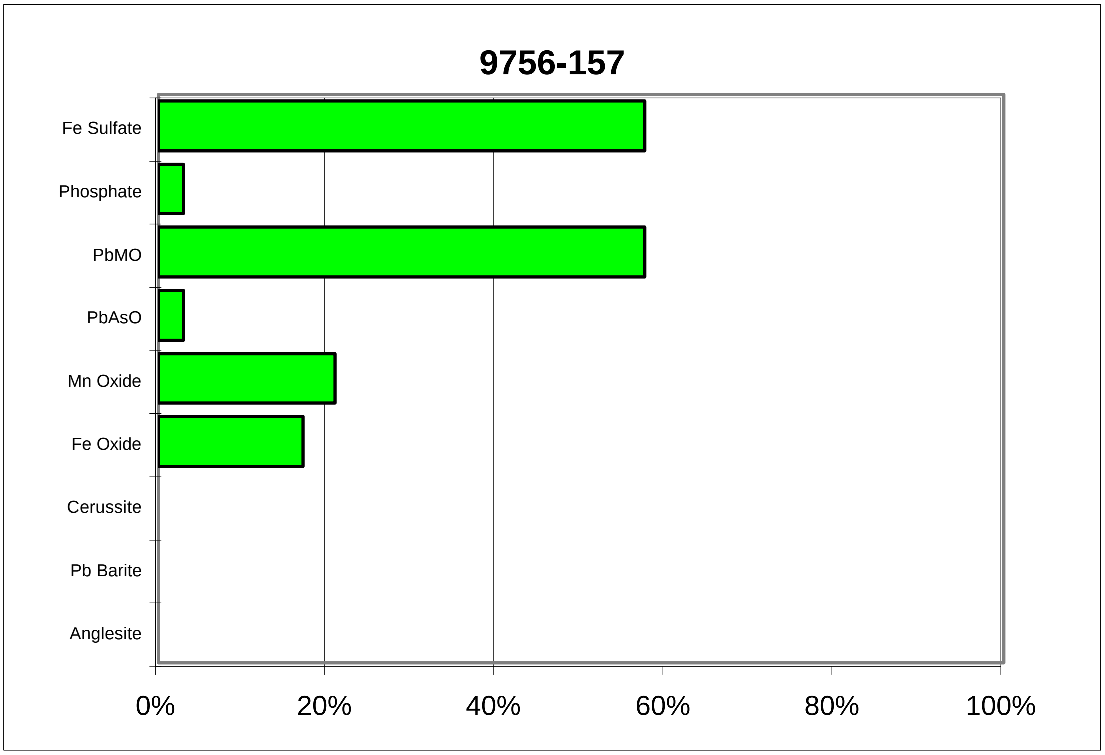


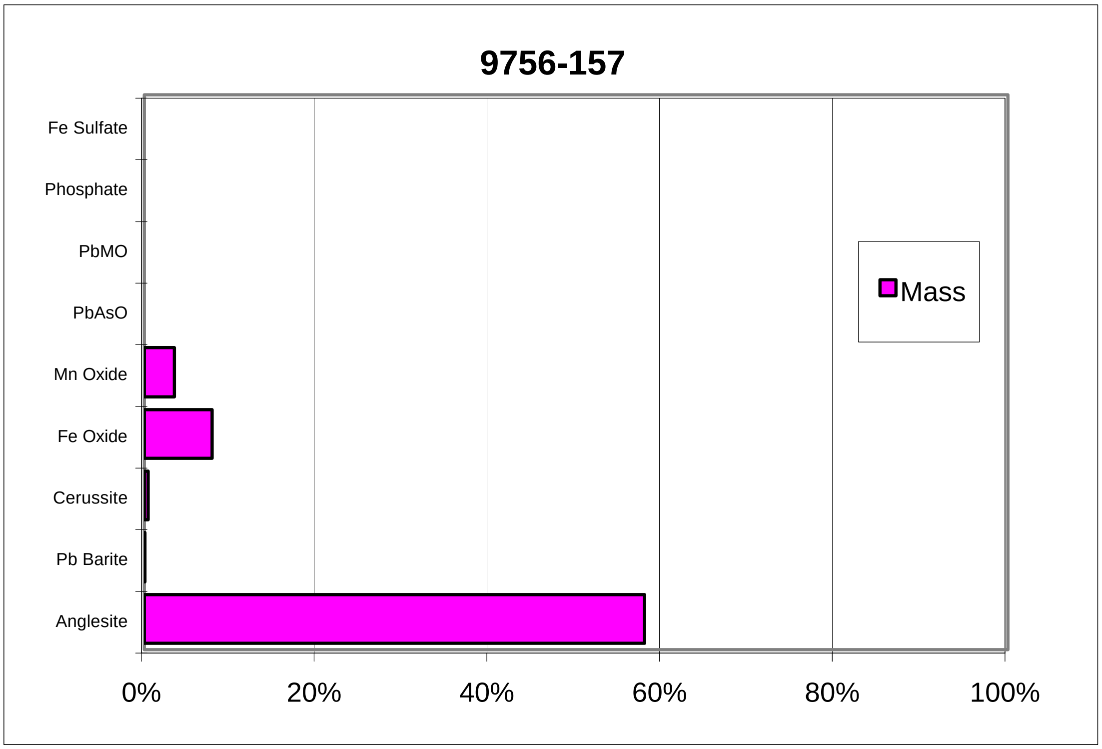
FIGURE 1 PARTICLE SIZE DISTRIBUTION



RELATIVE ARSENIC MASS



RELATIVE LEAD MASS



	9756-157 - As		9756-157 - Pb	
Mineral	Freq	Mass	Freq	Mass
Anglesite	17.0%	0.00%	17.0%	57.9%
Pb Barite	0.3%	0.00%	0.3%	0.1%
Cerussite	0.1%	0.00%	0.1%	0.4%
Fe Oxide	41.3%	17.14%	41.3%	7.8%
Mn Oxide	1.1%	20.86%	1.1%	3.5%
PbAsO	8.2%	2.92%	0.0%	0.0%
PbMO	21.3%	57.52%	0.0%	0.0%
Phosphate	8.2%	2.92%	0.0%	0.0%
Fe Sulfate	21.3%	57.52%	0.0%	0.0%

Size	9756-157 - As	9756-157 - Pb
<5	37.4%	37.4%
5-9	10.4%	10.4%
10-19	16.5%	16.5%
20-49	17.4%	17.4%
50-99	13.9%	13.9%
100-149	4.3%	4.3%
150-199	0.0%	0.0%
200-249	0.0%	0.0%
≥250	0.0%	0.0%

SUMMARY STATISTICS
9767-766 - Arsenic

	COUNTS		SIZE			Count Freq (%)		LW Freq (%)				Relative Arsenic Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract As	Total	Liberated
Fe Oxide	51	51	15	1	80	50.0%	50.0%	70.11%	70.11%	4	0.0064	27.5%	27.5%
Mn Oxide	26	26	9	2	35	25.5%	25.5%	21.60%	21.60%	5	0.0014	2.3%	2.3%
PbAsO	7	7	5	1	13	6.9%	6.9%	3.26%	3.26%	7.1	0.16	56.7%	56.7%
PbMO	8	8	4	1	12	7.8%	7.8%	2.98%	2.98%	7.1	0.03	9.7%	9.7%
Phosphate	7	7	1	1	1	6.9%	6.9%	0.65%	0.65%	5	0.0044	0.2%	0.2%
Fe Sulfate	3	3	5	3	8	2.9%	2.9%	1.40%	1.40%	3.7	0.045	3.6%	3.6%
TOTAL	102	102	11			100.0%	100.0%	100.00%	100.00%			100.0%	100.0%

DISTRIBUTION				
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	39.2%	39.2%	18.4%	18.4%
5-9	26.5%	26.5%	32.6%	32.6%
10-19	19.6%	19.6%	31.4%	31.4%
20-49	13.7%	13.7%	14.6%	14.6%
50-99	1.0%	1.0%	2.9%	2.9%
100-149	0.0%	0.0%	0.0%	0.0%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	100%	100%	100%

SUMMARY STATISTICS
9767-766 -Lead

	COUNTS			SIZE		Count Freq (%)		LW Freq (%)				Relative Lead Mass (%)	
Mineral	Total	Lib	Avg	Min	Max	Total	Liberated	Total	Liberated	Density	Fract Pb	Total	Liberated
Fe Oxide	51	51	15	1	80	50.0%	50.0%	70.11%	70.11%	4	0.06	31.7%	31.7%
Mn Oxide	26	26	9	2	35	25.5%	25.5%	21.60%	21.60%	5	0.13	26.5%	26.5%
PbAsO	7	7	5	1	13	6.9%	6.9%	3.26%	3.26%	7.1	0.55	24.0%	24.0%
PbMO	8	8	4	1	12	7.8%	7.8%	2.98%	2.98%	7.1	0.34	13.6%	13.6%
Phosphate	7	7	1	1	1	6.9%	6.9%	0.65%	0.65%	5	0.418	2.6%	2.6%
Fe Sulfate	3	3	5	3	8	2.9%	2.9%	1.40%	1.40%	3.7	0.18	1.8%	1.8%

	DISTRIBUTION			
Size	Total Freq	Lib Freq	Total RAM	Lib RAM
<5	39.2%	39.2%	17.7%	17.7%
5-9	26.5%	26.5%	24.6%	24.6%
10-19	19.6%	19.6%	31.4%	31.4%
20-49	13.7%	13.7%	22.9%	22.9%
50-99	1.0%	1.0%	3.4%	3.4%
100-149	0.0%	0.0%	0.0%	0.0%
150-199	0.0%	0.0%	0.0%	0.0%
200-249	0.0%	0.0%	0.0%	0.0%
≥250	0.0%	0.0%	0.0%	0.0%
	100%	100%	100%	100%

MINERAL FREQUENCY OBSERVED IN SITE SOIL

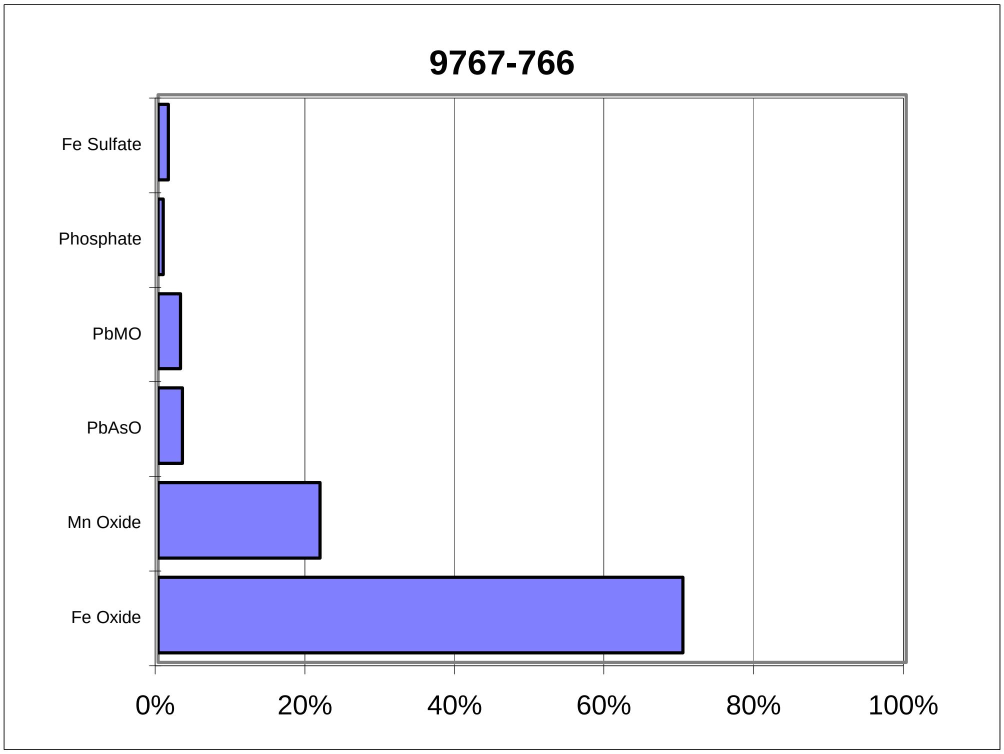
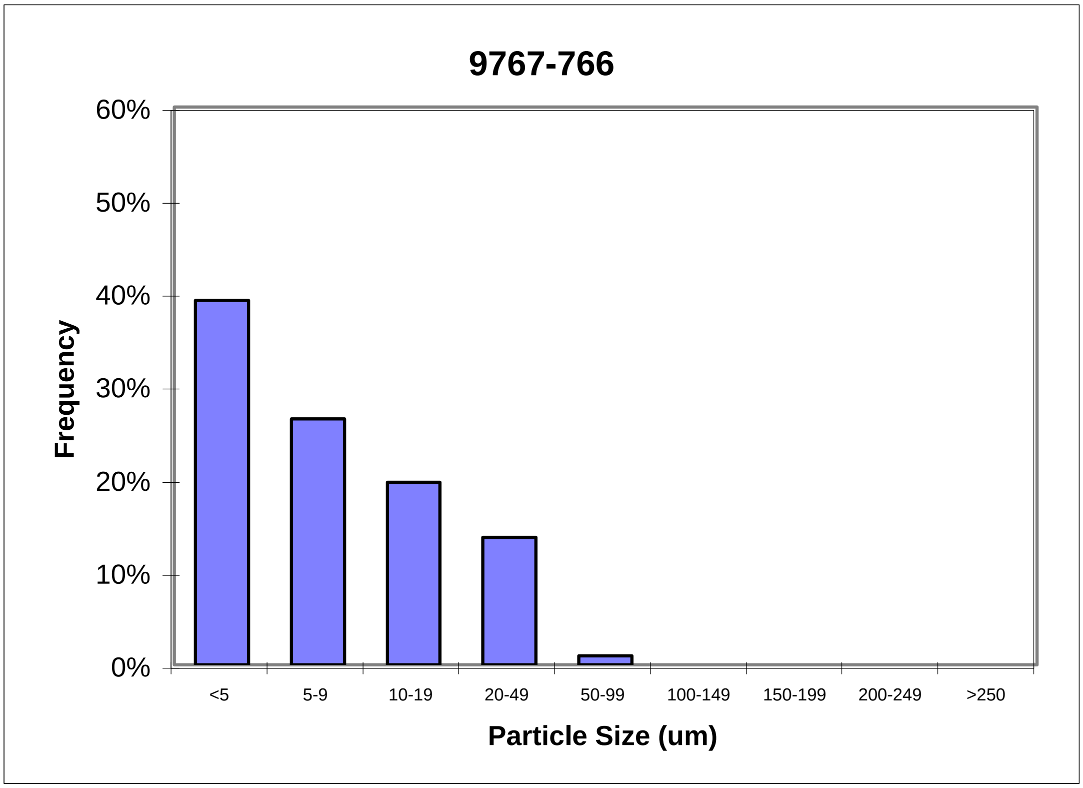
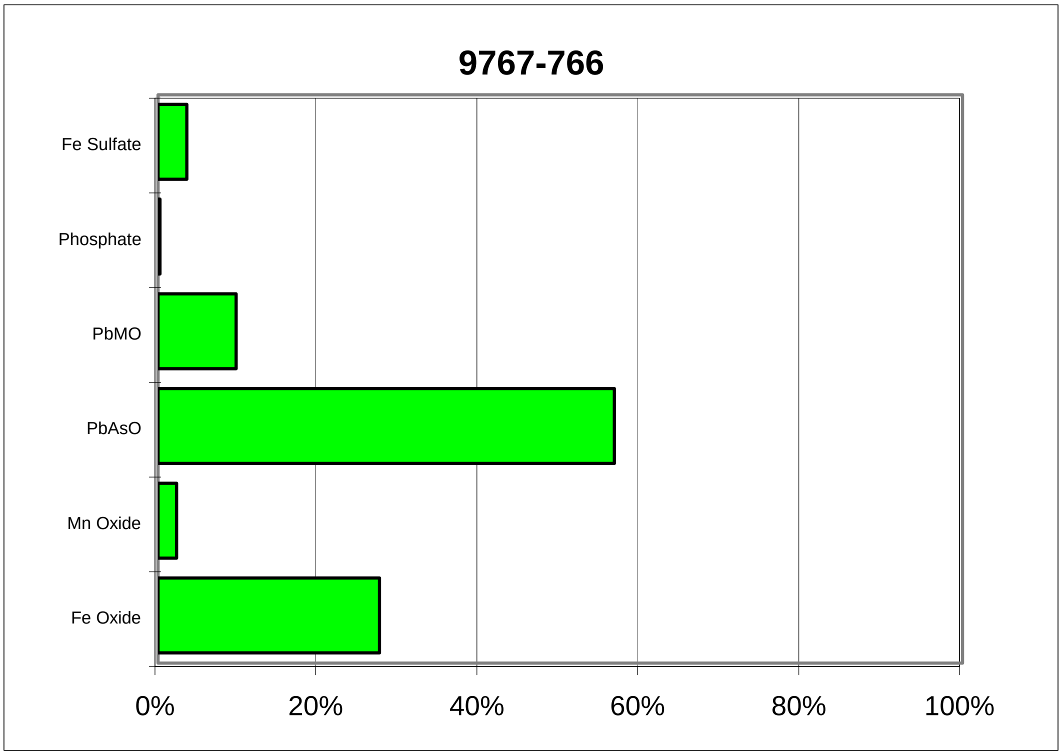


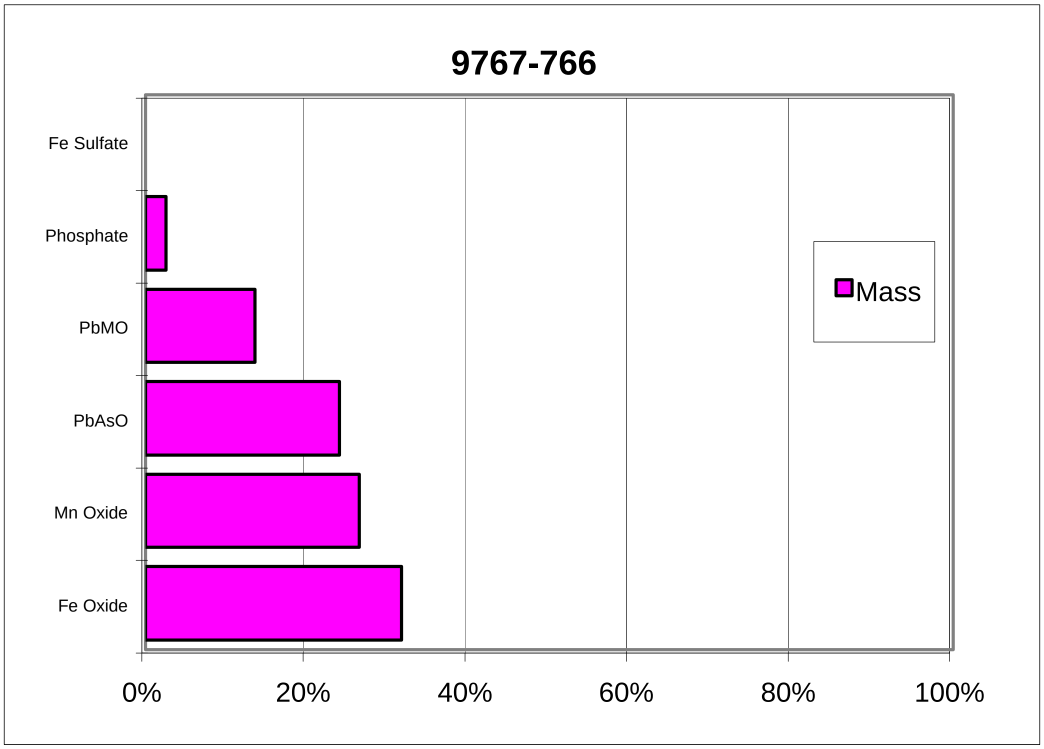
FIGURE 1 PARTICLE SIZE DISTRIBUTION



RELATIVE ARSENIC MASS



RELATIVE LEAD MASS



Summary

	9767-766 - As		9767-766 - Pb	
Mineral	Freq	Mass	Freq	Mass
Fe Oxide	70.1%	27.49%	70.1%	31.7%
Mn Oxide	21.6%	2.32%	21.6%	26.5%
PbAsO	3.3%	56.70%	3.3%	24.0%
PbMO	3.0%	9.72%	3.0%	13.6%
Phosphate	0.7%	0.22%	0.7%	2.6%
Fe Sulfate	1.4%	3.56%	0.0%	0.0%

Size	9767-766 - As	9767-766 - Pb
<5	39.2%	39.2%
5-9	26.5%	26.5%
10-19	19.6%	19.6%
20-49	13.7%	13.7%
50-99	1.0%	1.0%
100-149	0.0%	0.0%
150-199	0.0%	0.0%
200-249	0.0%	0.0%
≥250	0.0%	0.0%

APPENDIX 6 DETAILED RISK CALCULATIONS FOR ARSENIC

Zone	Arsenic (mg/kg)							
	N	Min	Max	Average	StdDev	UCL 95 (N)	UCL 95 (LN)	EPC
A	32	11	64	23.3	11.8	26.8	26.4	27
B	42	9	370	54.4	76.0	74.1	68.1	74
All C	146	5	650	31.1	73.4	41.2	28.3	41
C1	29	10	650	77.3	148.3	124.2	103.8	124
C2	38	5	39	15.1	8.9	17.5	17.7	18
C3	12	7	17	10.7	2.8	12.1	12.4	12
C4	67	5	190	23.9	35.4	31.1	25.7	31
C1+C3	41	7	650	57.8	127.9	91.4	65.4	91
C2+C4	105	5	190	20.7	29.0	25.4	21.3	25
C1+C2	67	5	650	42.0	101.7	62.8	41.0	63
C3+C4	79	5	190	21.9	32.9	28.1	22.5	28
ALL	220	5	650	34	69	42	32.4	42

EXPOSURE AND RISK CALCULATIONS FOR FLAGSTAFF/DAVENPORT

CONCENTRATION DATA FOR ARSENIC IN SURFACE SOIL (ppm)

Zone	N	Mean	Min	Max	EPC
A	32	23.3	11.0	64.0	26.8
B	42	54.4	9.0	370.0	74.1
All C	146	31.1	5.0	650.0	41.2
C1	29	77.3	10.0	650.0	124.2
C2	38	15.1	5.0	39.0	17.7
C3	12	10.7	7.0	17.0	12.4
C4	67	23.9	5.0	190.0	31.1
C1+C3	41	57.8	7.0	650.0	91.4
C2+C4	105	20.7	5.0	190.0	25.4
C1+C2	67	42.0	5.0	650.0	62.8
C3+C4	79	21.9	5.0	190.0	28.1
ALL	220	34.4	5.0	650.0	42.1

EXPOSURE AND RISK CALCULATIONS FOR FLAGSTAFF/DAVENPORT

HUMAN EXPOSURE PARAMETERS AND HIFs

		Resident	
Scenario	**Parameter**	**Avg**	**RME**
Ingestion of	IR (mg/d) total as child	100	200
soil and dust	IR (mg/d) total as adult	50	100
	Fraction soil	0.45	0.45
	BW (kg) as child	15	15
	BW (kg) as adult	70	70
	EF(d/yr)	234	350
	ED (yr) as child	2	6
	ED (yr) as adult	7	24
	ED (y) total	9	30
	AT (chronic)	9	30
	AT (lifetime)	70	70
Soil + Dust	cHIFs	1.31E-06	3.65E-06
	lHIFs	1.68E-07	1.57E-06
Soil	cHIFs	5.88E-07	1.64E-06
	lHIFs	7.56E-08	7.05E-07
Dust	cHIFd	7.18E-07	2.01E-06
	lHIFd	9.23E-08	8.61E-07

EXPOSURE AND RISK CALCULATIONS FOR FLAGSTAFF/DAVENPORT

Toxicity Factors

	Oral Exposure	
	oRfD	oSF
Arsenic	3.0E-04	1.5

Bioavailability factors

	Soil	Dust
Arsenic	0.51	0.51

Soil/Dust Relationship

	D0	Ksd
Arsenic	20	0.23

EXPOSURE AND RISK CALCULATIONS FOR FLAGSTAFF/DAVENPORT

MEDIUM: SURFACE SOIL AND DUST
POPULATION: RESIDENTS
ROUTE: INGESTION

CANCER RISKS

PART A: ARSENIC

Exposure						Average											RME				
Location	**EPC**	**HIFs**	**HIFd**	**RBAs**	**RBAd**	**D0**	**Ksd**	**DIsd**	**oSF**	**Risk**	**EPC**	**HIFs**	**HIFd**	**RBAs**	**RBAd**	**D0**	**Ksd**	**DIsd**	**oSF**	**Risk**
A	27	7.56E-08	9.23E-08	0.51	0.51	20	0.23	2.3E-06	1.5E+00	3.4E-06	27	7.05E-07	8.61E-07	0.51	0.51	20	0.23	2.1E-05	1.5E+00	3.2E-05
B	74	7.56E-08	9.23E-08	0.51	0.51	20	0.23	4.6E-06	1.5E+00	6.9E-06	74	7.05E-07	8.61E-07	0.51	0.51	20	0.23	4.3E-05	1.5E+00	6.4E-05
All C	41	7.56E-08	9.23E-08	0.51	0.51	20	0.23	3.0E-06	1.5E+00	4.5E-06	41	7.05E-07	8.61E-07	0.51	0.51	20	0.23	2.8E-05	1.5E+00	4.2E-05
C1	124	7.56E-08	9.23E-08	0.51	0.51	20	0.23	7.1E-06	1.5E+00	1.1E-05	124	7.05E-07	8.61E-07	0.51	0.51	20	0.23	6.6E-05	1.5E+00	9.9E-05
C2	18	7.56E-08	9.23E-08	0.51	0.51	20	0.23	1.8E-06	1.5E+00	2.7E-06	18	7.05E-07	8.61E-07	0.51	0.51	20	0.23	1.7E-05	1.5E+00	2.5E-05
C3	12	7.56E-08	9.23E-08	0.51	0.51	20	0.23	1.6E-06	1.5E+00	2.3E-06	12	7.05E-07	8.61E-07	0.51	0.51	20	0.23	1.4E-05	1.5E+00	2.2E-05
C4	31	7.56E-08	9.23E-08	0.51	0.51	20	0.23	2.5E-06	1.5E+00	3.7E-06	31	7.05E-07	8.61E-07	0.51	0.51	20	0.23	2.3E-05	1.5E+00	3.5E-05
C1+C3	91	7.56E-08	9.23E-08	0.51	0.51	20	0.23	5.5E-06	1.5E+00	8.2E-06	91	7.05E-07	8.61E-07	0.51	0.51	20	0.23	5.1E-05	1.5E+00	7.6E-05
C2+C4	25	7.56E-08	9.23E-08	0.51	0.51	20	0.23	2.2E-06	1.5E+00	3.3E-06	25	7.05E-07	8.61E-07	0.51	0.51	20	0.23	2.0E-05	1.5E+00	3.1E-05
C1+C2	63	7.56E-08	9.23E-08	0.51	0.51	20	0.23	4.0E-06	1.5E+00	6.1E-06	63	7.05E-07	8.61E-07	0.51	0.51	20	0.23	3.8E-05	1.5E+00	5.7E-05
C3+C4	28	7.56E-08	9.23E-08	0.51	0.51	20	0.23	2.3E-06	1.5E+00	3.5E-06	28	7.05E-07	8.61E-07	0.51	0.51	20	0.23	2.2E-05	1.5E+00	3.3E-05
ALL	42	7.56E-08	9.23E-08	0.51	0.51	20	0.23	3.0E-06	1.5E+00	4.5E-06	42	7.05E-07	8.61E-07	0.51	0.51	20	0.23	2.8E-05	1.5E+00	4.2E-05

SUMMARY

Location	Avg	RME
A	3E-06	3E-05
B	7E-06	6E-05
All C	4E-06	4E-05
C1	1E-05	1E-04
C2	3E-06	3E-05
C3	2E-06	2E-05
C4	4E-06	3E-05
ALL	5E-06	4E-05

EXPOSURE AND RISK CALCULATIONS FOR FLAGSTAFF/DAVENPORT

MEDIUM: SURFACE SOIL AND DUST
POPULATION: RESIDENTS
ROUTE: INGESTION

NONCANCER RISKS

PART A: ARSENIC

Exposure	Average										RME									
Location	EPC	HIFs	HIFd	RBAs	RBAd	D0	Ksd	DIsd	cRfD	HQsd	EPC	HIFs	HIFd	RBAs	RBAd	D0	Ksd	DIsd	cRfD	HQsd
A	27	5.88E-07	7.18E-07	0.51	0.51	20	0.23	1.8E-05	3.0E-04	5.87E-02	27	1.64E-06	2.01E-06	0.51	0.51	20	0.23	4.9E-05	3.0E-04	2E-01
B	74	5.88E-07	7.18E-07	0.51	0.51	20	0.23	3.6E-05	3.0E-04	1E-01	74	1.64E-06	2.01E-06	0.51	0.51	20	0.23	1.0E-04	3.0E-04	3E-01
All C	41	5.88E-07	7.18E-07	0.51	0.51	20	0.23	2.3E-05	3.0E-04	8E-02	41	1.64E-06	2.01E-06	0.51	0.51	20	0.23	6.5E-05	3.0E-04	2E-01
C1	124	5.88E-07	7.18E-07	0.51	0.51	20	0.23	5.5E-05	3.0E-04	2E-01	124	1.64E-06	2.01E-06	0.51	0.51	20	0.23	1.5E-04	3.0E-04	5E-01
C2	18	5.88E-07	7.18E-07	0.51	0.51	20	0.23	1.4E-05	3.0E-04	5E-02	18	1.64E-06	2.01E-06	0.51	0.51	20	0.23	4.0E-05	3.0E-04	1E-01
C3	12	5.88E-07	7.18E-07	0.51	0.51	20	0.23	1.2E-05	3.0E-04	4E-02	12	1.64E-06	2.01E-06	0.51	0.51	20	0.23	3.4E-05	3.0E-04	1E-01
C4	31	5.88E-07	7.18E-07	0.51	0.51	20	0.23	1.9E-05	3.0E-04	6E-02	31	1.64E-06	2.01E-06	0.51	0.51	20	0.23	5.4E-05	3.0E-04	2E-01
C1+C3	91	5.88E-07	7.18E-07	0.51	0.51	20	0.23	4.2E-05	3.0E-04	1E-01	91	1.64E-06	2.01E-06	0.51	0.51	20	0.23	1.2E-04	3.0E-04	4E-01
C2+C4	25	5.88E-07	7.18E-07	0.51	0.51	20	0.23	1.7E-05	3.0E-04	6E-02	25	1.64E-06	2.01E-06	0.51	0.51	20	0.23	4.8E-05	3.0E-04	2E-01
C1+C2	63	5.88E-07	7.18E-07	0.51	0.51	20	0.23	3.1E-05	3.0E-04	1E-01	63	1.64E-06	2.01E-06	0.51	0.51	20	0.23	8.8E-05	3.0E-04	3E-01
C3+C4	28	5.88E-07	7.18E-07	0.51	0.51	20	0.23	1.8E-05	3.0E-04	6E-02	28	1.64E-06	2.01E-06	0.51	0.51	20	0.23	5.1E-05	3.0E-04	2E-01
ALL	42	5.88E-07	7.18E-07	0.51	0.51	20	0.23	2.4E-05	3.0E-04	8E-02	42	1.64E-06	2.01E-06	0.51	0.51	20	0.23	6.6E-05	3.0E-04	2E-01

SUMMARY

Exposure Location	Average HQ As	RME HQ As
A	6E-02	2E-01
B	1E-01	3E-01
All C	8E-02	2E-01
C1	2E-01	5E-01
C2	5E-02	1E-01
C3	4E-02	1E-01
C4	6E-02	2E-01
ALL	8E-02	2E-01

Zone	Arsenic (mg/kg)							
	N	Min	Max	Average	StdDev	UCL 95 (N)	UCL 95 (LN)	EPC
A	32	11	64	23.3	11.8	26.8	26.4	27
B	42	9	370	54.4	76.0	74.1	68.1	74
All C	146	5	650	31.1	73.4	41.2	28.3	41
C1	29	10	650	77.3	148.3	124.2	103.8	124
C2	38	5	39	15.1	8.9	17.5	17.7	18
C3	12	7	17	10.7	2.8	12.1	12.4	12
C4	67	5	190	23.9	35.4	31.1	25.7	31
C1+C3	41	7	650	57.8	127.9	91.4	65.4	91
C2+C4	105	5	190	20.7	29.0	25.4	21.3	25
C1+C2	67	5	650	42.0	101.7	62.8	41.0	63
C3+C4	79	5	190	21.9	32.9	28.1	22.5	28
ALL	220	5	650	34	69	42	32.4	42

EXPOSURE AND RISK CALCULATIONS FOR FLAGSTAFF/DAVENPORT

CONCENTRATION DATA FOR ARSENIC IN SURFACE SOIL (ppm)

Zone	N	Mean	Min	Max	EPC
A	32	23.3	11.0	64.0	26.8
B	42	54.4	9.0	370.0	74.1
All C	146	31.1	5.0	650.0	41.2
C1	29	77.3	10.0	650.0	124.2
C2	38	15.1	5.0	39.0	17.7
C3	12	10.7	7.0	17.0	12.4
C4	67	23.9	5.0	190.0	31.1
C1+C3	41	57.8	7.0	650.0	91.4
C2+C4	105	20.7	5.0	190.0	25.4
C1+C2	67	42.0	5.0	650.0	62.8
C3+C4	79	21.9	5.0	190.0	28.1
ALL	220	34.4	5.0	650.0	42.1

EXPOSURE AND RISK CALCULATIONS FOR FLAGSTAFF/DAVENPORT

HUMAN EXPOSURE PARAMETERS AND HIFs

		Resident	
Scenario	**Parameter**	**Avg**	**RME**
Ingestion of	IR (mg/d) total as child	100	200
soil and dust	IR (mg/d) total as adult	50	100
	Fraction soil	0.45	0.45
	BW (kg) as child	15	15
	BW (kg) as adult	70	70
	EF(d/yr)	234	350
	ED (yr) as child	2	6
	ED (yr) as adult	7	24
	ED (y) total	9	30
	AT (chronic)	9	30
	AT (lifetime)	70	70
Soil + Dust	cHIFs	1.31E-06	3.65E-06
	lHIFs	1.68E-07	1.57E-06
Soil	cHIFs	5.88E-07	1.64E-06
	lHIFs	7.56E-08	7.05E-07
Dust	cHIFd	7.18E-07	2.01E-06
	lHIFd	9.23E-08	8.61E-07

EXPOSURE AND RISK CALCULATIONS FOR FLAGSTAFF/DAVENPORT

Toxicity Factors

	Oral Exposure	
	oRfD	oSF
Arsenic	3.0E-04	1.5

Bioavailability factors

	Soil	Dust
Arsenic	0.80	0.80

Soil/Dust Relationship

	D0	Ksd
Arsenic	20	0.23

EXPOSURE AND RISK CALCULATIONS FOR FLAGSTAFF/DAVENPORT

MEDIUM: **SURFACE SOIL AND DUST**
POPULATION: **RESIDENTS**
ROUTE: **INGESTION**

NONCANCER RISKS

PART A: ARSENIC

Exposure	Average										RME									
Location	EPC	HIFs	HIFd	RBAs	RBAd	D0	Ksd	DIsd	cRfD	HQsd	EPC	HIFs	HIFd	RBAs	RBAd	D0	Ksd	DIsd	cRfD	HQsd
A	27	5.88E-07	7.18E-07	0.80	0.80	20	0.23	2.8E-05	3.0E-04	9.21E-02	27	1.64E-06	2.01E-06	0.80	0.80	20	0.23	7.7E-05	3.0E-04	3E-01
B	74	5.88E-07	7.18E-07	0.80	0.80	20	0.23	5.6E-05	3.0E-04	2E-01	74	1.64E-06	2.01E-06	0.80	0.80	20	0.23	1.6E-04	3.0E-04	5E-01
All C	41	5.88E-07	7.18E-07	0.80	0.80	20	0.23	3.6E-05	3.0E-04	1E-01	41	1.64E-06	2.01E-06	0.80	0.80	20	0.23	1.0E-04	3.0E-04	3E-01
C1	124	5.88E-07	7.18E-07	0.80	0.80	20	0.23	8.6E-05	3.0E-04	3E-01	124	1.64E-06	2.01E-06	0.80	0.80	20	0.23	2.4E-04	3.0E-04	8E-01
C2	18	5.88E-07	7.18E-07	0.80	0.80	20	0.23	2.2E-05	3.0E-04	7E-02	18	1.64E-06	2.01E-06	0.80	0.80	20	0.23	6.2E-05	3.0E-04	2E-01
C3	12	5.88E-07	7.18E-07	0.80	0.80	20	0.23	1.9E-05	3.0E-04	6E-02	12	1.64E-06	2.01E-06	0.80	0.80	20	0.23	5.3E-05	3.0E-04	2E-01
C4	31	5.88E-07	7.18E-07	0.80	0.80	20	0.23	3.0E-05	3.0E-04	1E-01	31	1.64E-06	2.01E-06	0.80	0.80	20	0.23	8.5E-05	3.0E-04	3E-01
C1+C3	91	5.88E-07	7.18E-07	0.80	0.80	20	0.23	6.7E-05	3.0E-04	2E-01	91	1.64E-06	2.01E-06	0.80	0.80	20	0.23	1.9E-04	3.0E-04	6E-01
C2+C4	25	5.88E-07	7.18E-07	0.80	0.80	20	0.23	2.7E-05	3.0E-04	9E-02	25	1.64E-06	2.01E-06	0.80	0.80	20	0.23	7.5E-05	3.0E-04	2E-01
C1+C2	63	5.88E-07	7.18E-07	0.80	0.80	20	0.23	4.9E-05	3.0E-04	2E-01	63	1.64E-06	2.01E-06	0.80	0.80	20	0.23	1.4E-04	3.0E-04	5E-01
C3+C4	28	5.88E-07	7.18E-07	0.80	0.80	20	0.23	2.8E-05	3.0E-04	9E-02	28	1.64E-06	2.01E-06	0.80	0.80	20	0.23	7.9E-05	3.0E-04	3E-01
ALL	42	5.88E-07	7.18E-07	0.80	0.80	20	0.23	3.7E-05	3.0E-04	1E-01	42	1.64E-06	2.01E-06	0.80	0.80	20	0.23	1.0E-04	3.0E-04	3E-01

SUMMARY

Exposure Location	Average HQ As	RME HQ As
A	9E-02	3E-01
B	2E-01	5E-01
All C	1E-01	3E-01
C1	3E-01	8E-01
C2	7E-02	2E-01
C3	6E-02	2E-01
C4	1E-01	3E-01
ALL	1E-01	3E-01

EXPOSURE AND RISK CALCULATIONS FOR FLAGSTAFF/DAVENPORT

MEDIUM: SURFACE SOIL AND DUST
POPULATION: RESIDENTS
ROUTE: INGESTION

CANCER RISKS

PART A: ARSENIC

Exposure	Average										RME									
Location	EPC	HIFs	HIFd	RBAs	RBAd	D0	Ksd	DIsd	oSF	Risk	EPC	HIFs	HIFd	RBAs	RBAd	D0	Ksd	DIsd	oSF	Risk
A	27	7.56E-08	9.23E-08	0.80	0.80	20	0.23	3.6E-06	1.5E+00	5.3E-06	27	7.05E-07	8.61E-07	0.80	0.80	20	0.23	3.3E-05	1.5E+00	5.0E-05
B	74	7.56E-08	9.23E-08	0.80	0.80	20	0.23	7.2E-06	1.5E+00	1.1E-05	74	7.05E-07	8.61E-07	0.80	0.80	20	0.23	6.7E-05	1.5E+00	1.0E-04
All C	41	7.56E-08	9.23E-08	0.80	0.80	20	0.23	4.7E-06	1.5E+00	7.0E-06	41	7.05E-07	8.61E-07	0.80	0.80	20	0.23	4.4E-05	1.5E+00	6.5E-05
C1	124	7.56E-08	9.23E-08	0.80	0.80	20	0.23	1.1E-05	1.5E+00	1.7E-05	124	7.05E-07	8.61E-07	0.80	0.80	20	0.23	1.0E-04	1.5E+00	1.6E-04
C2	18	7.56E-08	9.23E-08	0.80	0.80	20	0.23	2.9E-06	1.5E+00	4.3E-06	18	7.05E-07	8.61E-07	0.80	0.80	20	0.23	2.7E-05	1.5E+00	4.0E-05
C3	12	7.56E-08	9.23E-08	0.80	0.80	20	0.23	2.4E-06	1.5E+00	3.7E-06	12	7.05E-07	8.61E-07	0.80	0.80	20	0.23	2.3E-05	1.5E+00	3.4E-05
C4	31	7.56E-08	9.23E-08	0.80	0.80	20	0.23	3.9E-06	1.5E+00	5.8E-06	31	7.05E-07	8.61E-07	0.80	0.80	20	0.23	3.6E-05	1.5E+00	5.4E-05
C1+C3	91	7.56E-08	9.23E-08	0.80	0.80	20	0.23	8.6E-06	1.5E+00	1.3E-05	91	7.05E-07	8.61E-07	0.80	0.80	20	0.23	8.0E-05	1.5E+00	1.2E-04
C2+C4	25	7.56E-08	9.23E-08	0.80	0.80	20	0.23	3.4E-06	1.5E+00	5.2E-06	25	7.05E-07	8.61E-07	0.80	0.80	20	0.23	3.2E-05	1.5E+00	4.8E-05
C1+C2	63	7.56E-08	9.23E-08	0.80	0.80	20	0.23	6.3E-06	1.5E+00	9.5E-06	63	7.05E-07	8.61E-07	0.80	0.80	20	0.23	5.9E-05	1.5E+00	8.9E-05
C3+C4	28	7.56E-08	9.23E-08	0.80	0.80	20	0.23	3.6E-06	1.5E+00	5.5E-06	28	7.05E-07	8.61E-07	0.80	0.80	20	0.23	3.4E-05	1.5E+00	5.1E-05
ALL	42	7.56E-08	9.23E-08	0.80	0.80	20	0.23	4.7E-06	1.5E+00	7.1E-06	42	7.05E-07	8.61E-07	0.80	0.80	20	0.23	4.4E-05	1.5E+00	6.6E-05

SUMMARY

Location	Avg	RME
A	5E-06	5E-05
B	1E-05	1E-04
All C	7E-06	7E-05
C1	2E-05	2E-04
C2	4E-06	4E-05
C3	4E-06	3E-05
C4	6E-06	5E-05
ALL	7E-06	7E-05

APPENDIX 7 CORRESPONDENCE REGARDING PROBABILISTIC RISK ASSESSMENT

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
SOLID WASTE AND EMERGENCY RESPONSE

May 17, 1999

MEMORANDUM

SUBJECT: Use of the Integrated Stochastic Exposure (ISE) Model in the Jacobs Smelter risk assessment

FROM: Stephen D. Luftig, Director
Office of Emergency and Remedial Response

TO: Max H. Dodson, Assistant Regional Administrator, 8EPR
Office of Ecosystems Protection & Remediation

I am writing this memo in response to your request for guidance on the use of the Integrated Stochastic Exposure Model (ISE) in conjunction with the Jacobs Smelter Risk Assessment. Given your need for an answer that will be responsive to your schedule and the very limited window for review, I will address question 5 in this memo and refer the other questions to the Technical Review Workgroup for Lead and David Cooper, the Senior Process Manager for Risk.

In response to question 5 (i.e., should all references to the ISE model be removed from the Jacobs Smelter risk assessment), I must restate our conclusion from the May 19, 1998 memo that found the ISE had not received sufficient review to serve as a reasonable tool for assessing lead risks. Therefore, reference to use of the ISE should not be incorporated in any risk assessment documentation relating to this site.

We look forward, however, to the use of probabilistic risk methods, where appropriate. As stated in the May 19, 1998 memo, the TRW has established a group to review probabilistic risk methods but this group has not received materials that are essential for this review to take place. However, since the

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8
999 18TH STREET - SUITE 500
DENVER, CO 80202-2466
http://www.epa.gov/region08

MAY 27 1999

Ref: 8EPR-IO

MEMORANDUM

Subject: Use of Integrated Stochastic Exposure (ISE) Model of the Jacobs Smelter Risk Assessment

From: Max H. Dodson Max H Dodson

To: Bill Murray
Susan Griffin

I had a conversation on the telephone with Steve Luftig on May 25, 1999, regarding the subject of the ISE Model on the Jacobs Smelter Risk Assessment. My purpose was to ascertain the efficacy of his request to remove the ISE Model results from the Risk Assessment. He reiterated his position that is has not received adequate scientific review to allow it to be included in the Risk Assessment and it should be removed.

I did request that we, as an Agency, should continue to discuss this issue and that ultimately it should be concluded with a definitive policy statement and that Region VIII would like to participate in whatever deliberation the TRW and others would embark upon. He agreed that our continued involvement would be appreciated.

On the basis of this conversation, and the May 17th correspondence (attached), I respectfully request that the ISE Model results be removed from the Risk Assessment. If either of you would like to discuss this further, please let me know.

Attachment

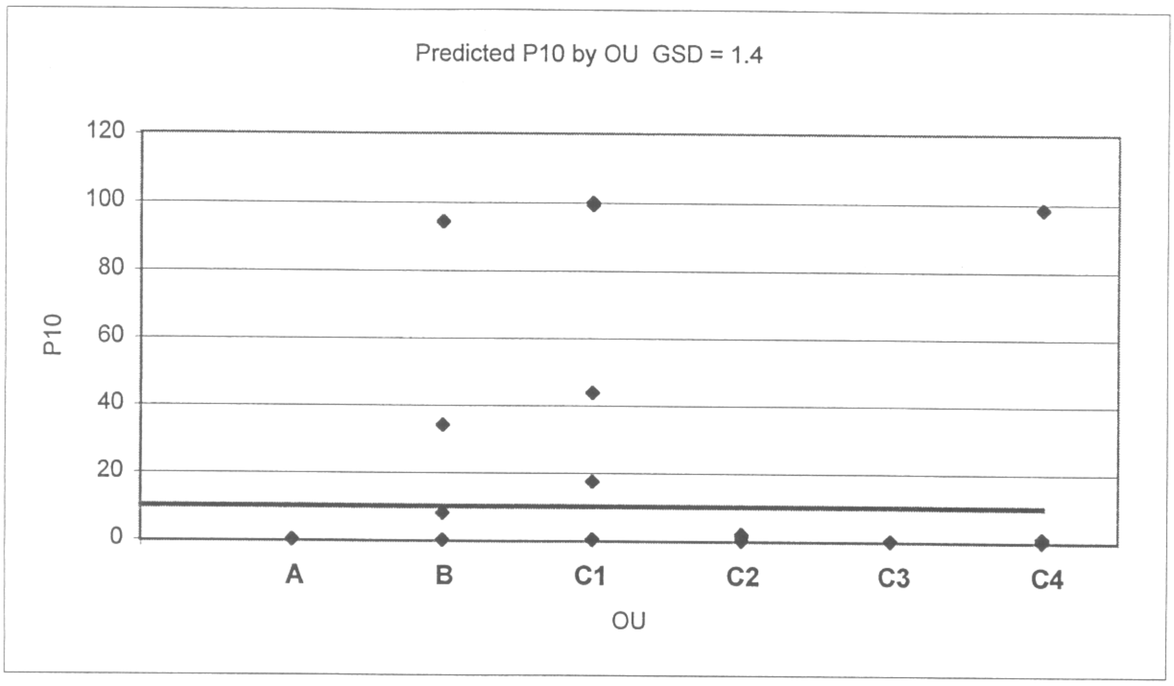
cc: Steve Luftig

Jacobs Smelter Risk Assessment, as presented for review, includes the application of the ISE, I am asking the TRW to review this risk assessment, to request any additional information that would be needed for a review of the ISE model, and to respond to questions 1-4. I have requested that the TRW provide a status report to us within the next month.

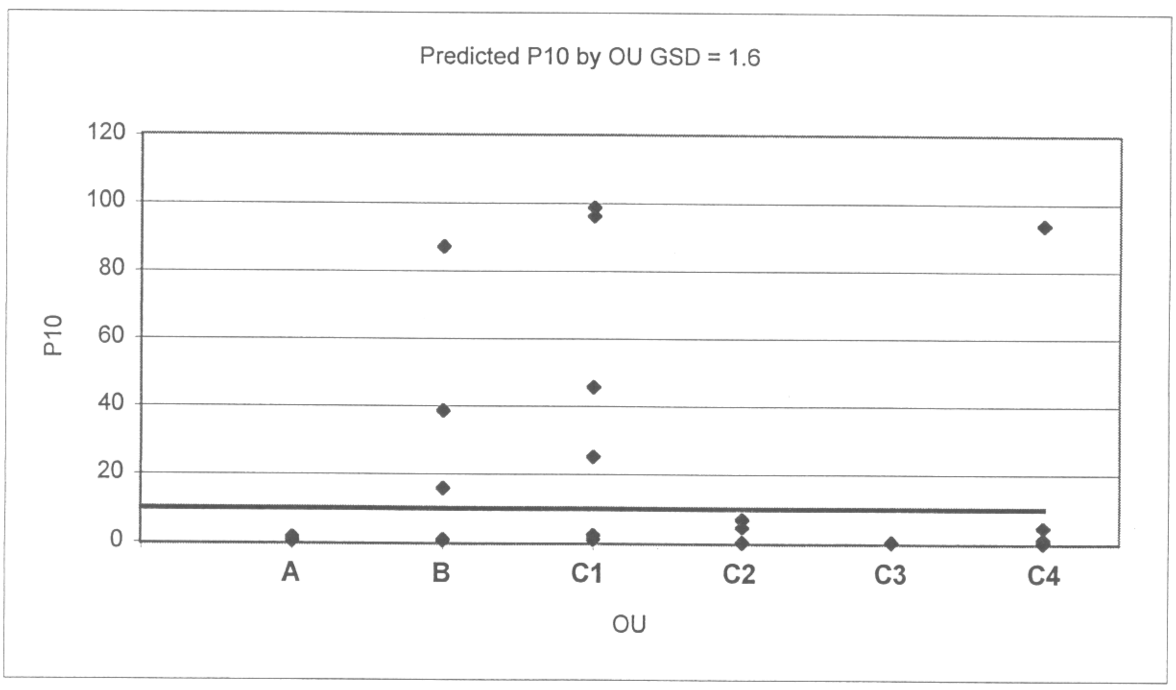
We look forward to working with your staff to address the technical review of the ISE. We are hopeful that this effort should help us to build agreement on how Superfund should move forward in the area of probabilistic risk methods for lead. Should you have any questions on this memo, please contact Tom Sheckells of my staff.

cc: T. Sheckells
D. Cooper
TRW Co-chairs

APPENDIX 8 IEUBK MODEL INPUTS AND RESULTS



Predicted P10 by OU GSD = 1.4
P10
120
100
80
60
40
20
0
A
B
C1
C2
C3
C4
OU



Predicted P10 by OU GSD = 1.6
P10
120
100
80
60
40
20
0
A
B
C1
C2
C3
C4
OU

ID	Property	Zone	Zone Code	AGE	SOIL	DUST	WATER	AIR	PAINT	PBB	PRED	GSD=1.4 P10	GSD=1.6 P10
				mo	ug/g	ug/g	ug/L	ug/m3	ug/day	ug/dL	ug/dL		
15	9516 Glacier Lane	A	1	51	190	172	1	0.1	0	---	2.85	0.01	0.38
16	9520 Glacier Lane	A	1	51	195	174	1	0.1	0	---	2.88	0.01	0.40
17	9600 Glacier Lane	A	1	51	203	177	1	0.1	0	---	2.94	0.01	0.46
18	9612 Glacier Lane	A	1	51	232	190	1	0.1	0	---	3.16	0.03	0.71
19	9650 Glacier Lane	A	1	51	293	216	1	0.1	0	---	3.59	0.12	1.46
8	3656 N. Little Cottonwood Road	B	2	51	2810	1298	1	0.1	0	---	17.02	94.30	87.11
9	3660 N. Little Cottonwood Road	B	2	51	1092	560	1	0.1	0	---	8.72	34.20	38.54
12	3710 N. Little Cottonwood Road	B	2	51	684	384	1	0.1	0	---	6.24	8.05	15.78
13	3742 N. Little Cottonwood Road	B	2	51	234	191	1	0.1	0	---	3.17	0.03	0.73
14	3744 N. Little Cottonwood Road	B	2	51	220	185	1	0.1	0	---	3.07	0.02	0.60
22	9696 Quail Ridge Road	C1	3	51	332	233	1	0.1	0	---	3.87	0.24	2.17
23	9712 Quail Ridge Road	C1	3	51	1228	618	1	0.1	0	---	9.49	43.82	45.57
25	9726 Quail Ridge Road	C1	3	51	853	457	1	0.1	0	---	7.3	17.48	25.16
31	9756 Quail Ridge Road	C1	3	51	258	201	1	0.1	0	---	3.34	0.06	0.98
36	9808 Little Cottonwood Lane	C1	3	51	6256	2780	1	0.1	0	---	28.29	99.90	98.65
40	Slope on Little Cottonwood Lane	C1	3	51	4486	2019	1	0.1	0	---	23.09	99.36	96.25
2	3587 Little Cottonwood Lane	C2	4	51	487	300	1	0.1	0	---	4.95	1.83	6.73
4	3623 Little Cottonwood Lane	C2	4	51	92	130	1	0.1	0	---	2.12	0.00	0.05
6	3641 Little Cottonwood Lane	C2	4	51	89	128	1	0.1	0	---	2.09	0.00	0.04
10	3695 Little Cottonwood Lane	C2	4	51	95	131	1	0.1	0	---	2.14	0.00	0.05
20	9682 Quail Ridge Road	C2	4	51	425	273	1	0.1	0	---	4.52	0.91	4.56
21	9687 Quail Ridge Road	C2	4	51	492	302	1	0.1	0	---	4.98	1.91	6.90
24	9715 Quail Ridge Road	C2	4	51	33	104	1	0.1	0	---	1.66	0.00	0.01
29	9753 Quail Ridge Road	C2	4	51	160	159	1	0.1	0	---	2.63	0.00	0.22
1	3541 Little Cottonwood Canyon Rd.	C3	5	51	120	142	1	0.1	0	---	2.33	0.00	0.10
35	9795 Little Cottonwood Lane	C3	5	51	94	131	1	0.1	0	---	2.13	0.00	0.05
37	9815 Little Cottonwood Lane	C3	5	51	150	155	1	0.1	0	---	2.55	0.00	0.18
3	3601 Little Cottonwood Canyon Road (Al	C4	6	51	214	182	1	0.1	0	---	3.02	0.02	0.54
5	3626 Little Cottonwood Lane	C4	6	51	46	110	1	0.1	0	---	1.76	0.00	0.01
7	3652 Little Cottonwood Lane	C4	6	51	49	111	1	0.1	0	---	1.78	0.00	0.01
11	3698 Little Cottonwood Lane	C4	6	51	36	105	1	0.1	0	---	1.68	0.00	0.01
26	9751 Little Cottonwood Place	C4	6	51	58	115	1	0.1	0	---	1.85	0.00	0.02
27	9751 Old Ranch Place	C4	6	51	29	103	1	0.1	0	---	1.63	0.00	0.01
28	9752 Little Cottonwood Place	C4	6	51	37	106	1	0.1	0	---	1.69	0.00	0.01
30	9756 Old Ranch Place	C4	6	51	3725	1692	1	0.1	0	---	20.51	98.36	93.68
32	9759 Old Ranch Place	C4	6	51	222	185	1	0.1	0	---	3.08	0.02	0.61
33	9764 Little Cottonwood Place	C4	6	51	119	141	1	0.1	0	---	2.32	0.00	0.09
34	9767 Little Cottonwood Place	C4	6	51	421	271	1	0.1	0	---	4.49	0.87	4.42
38	Grow Park, Mountain Valley Way	C4	6	51	181	168	1	0.1	0	---	2.78	0.01	0.32
39	Little Cottonwood Canyon Rd. S. E. Vaca	C4	6	51	260	202	1	0.1	0	---	3.36	0.06	1.02